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SCHOOL OF GRADUATE STUDIES

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DEPARTMENT OF EARTH SCIENCES

Land Use/Land Cover Dynamics and Soil Degradation Assessment Using Remote Sensing and GIS: A Case Study of Jima Arjo Woreda (Western Ethiopia)

By

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Horn of Africa Regional Environment Centre and Network

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Acronym

AAU	=	Addis Ababa University
a.s.l.	=	above sea level
CSA	=	Central Statistical Authority
DEM	=	Digital Elevation Model
DN	=	Digital Number
EIGS	=	Ethiopian Institute of Geological Survey
EMA	=	Ethiopian Mapping Agency
ETM^{+}	=	Enhanced Thematic Mapper Plus
EMS	=	Electromagnetic Spectrum
FAO	=	Food and Agricultural Organization
GCS	=	Geographic Coordinate System
GIS	=	Geographic Information System
GLCF	=	Global Land Cover Facility
GPS	=	Global Position System
ha	=	hectare
IDW	=	Inverse Distance Weight
LU/ LC	=	Land Use/Land Cover
m	=	Meter
MCE	=	Multi Criteria Evaluation
MoA & RDE	=	Ministry of Agriculture and Rural Development of Ethiopia
MSS	=	Multi Spectral Scanner
NASA	=	National Aeronautics and Space Administration
NDVI	=	Normalized Difference Vegetation Index
NIR	=	Near Infra Red
NMA	=	National Metrological Agency
P. A.	=	Peasant Association
SRTM	=	Shuttle Radar Topographic Mission
t	=	Tones
TM	=	Thematic Mapper
UNEP	=	United Environment program
UNESCO	=	United Nations Educational, Scientific and Cultural Organization
USLE	=	Universal Soil Loss Equation
WGS	=	World Geodetic System
WLC	=	Weighted Linear Combination

Abstract

This study is aimed at assessing the spatio-temporal dynamics of land use/ land cover and soil degradation in Jima Arjo Woreda. Three different time landsat images (1973, 1986 and 2001) were classified into 7 major land use/cover classes through supervised classification: farm land, dense forest land, degraded forest land, open woodland, grassland, wet land and bare land.

Post-classification change detection among the image data has been conducted. Accordingly, farmland and bare land has expanded with 15326.6ha and 769.897ha, respectively. Although the expansion is not continuous; open woodland increased by 6825.2ha and grassland by 6392.4ha over the period. However, vegetations particularly dense forest and the degraded forest land and wetlands were reduced greatly at varying rates of change per annum. Dense forest dropped down by 1686.5ha, degraded forest land reduced by 4264.7 and wetland by 8184.1ha.

Land use/cover distribution across various slope categories and susceptibility to change has also assessed from the final state of the study period (2001) image data. With respect to land use/cove – slope distribution, steep slopes were made cultural landscapes (agricultural and settlement areas). Farm lands, particularly the intensively cultivated farms, were evident on steep slopes (above 25^0) and more than 60% of slopes above 12^0 were shared by the farmlands. Five levels of susceptibility to change: extremely susceptible, highly susceptible, moderately, low and none susceptible areas have been identified based on factors of accessibility, proximity to towns and rivers, agroclimate, soil, slope and the type of land cover in the area. Vegetations are signified as the most susceptible classes. This has been realized in that 94.1% of the high to extremely high susceptibility level has been shared by dense forests.

Soil Loss has been estimated using USLE model on the basis of the adapted methodology and parameters for Ethiopian highland conditions. The estimated soil loss for the study area ranges from 0.35 – 184.4t/ha/yr with mean annual loss of 20.6t/ha. Highly sever soil loss (>60t/ha/yr) has been recognized over 5.9% in the area. This is more evident on the farm lands. The low soil loss (<1t/ha/yr) experienced over 10% of the area where vegetations (particularly the grassland and dense forest land) were recognized.

Key Words: land use/land cover dynamics, land use/cover susceptibility to change, soil degradation, USLE, Annual Soil Loss Estimation

1. INTRODUCTION

1.1. Background of the Study

The transformation in human society has brought about tremendous expansion in the human capacity to transform the physical environment whether deliberately or inadvertently and whether for better or worse.

The diversity of land-use practices reflects the complex interaction of physical and human factors. Soil occupies a central position in this interaction. It is evident that, currently, a large area of formerly productive land has been rendered unproductive. It is related to the unsustainable use of the resources that involve destruction or disturbance to the natural or semi-natural ecosystem. A major consequence of ecosystem destruction and disturbance is that of soil degradation (Ellis and Mellor, 1995).

The present land use practices in many agriculture-based developing countries (like Ethiopia) are resulting in soil, forests, water and living organisms' degradations. Ethiopia is an agrarian nation, and currently a considerable portion of the country is seriously threatened by soil degradation. South western high-lands of Ethiopia, in which the study area Jima Arjo is located, were relatively settled recently, less densely populated and have good vegetation cover (Solomon Abate, 1994). However, the severity and rate of soil degradation in the region currently is indeed alarming.

1.2. Problem Statement and Justification

In Ethiopia, agriculture provides a livelihood for 90% of its population (MoA & RDE et al., 2005). The highlands of the country are favorable for human habitat and they are the most significant economic areas. But they have signified rugged topography dissected by deep gorges with slopes associated with diverse climate (Hurni, 1986). Such physiographic features require careful agro-ecologically sustainable management (World Bank, 2006).

At the inception of agriculture, most of the land cover of the country was believed to have been forest. Since then, forest clearance was started in favor of crop production. With the rapid growing population of the country, the event yet calls for more forest clearance for further farm expansion, grazing land and extraction of fuel and constructional wood (Krauer, 1988). The event contributed to soil erosion and degradation and currently considerable portion of the country is threatened by soil degradation.

Soil loss through water erosion is evident in Ethiopia and it was estimated that the country loses an estimated 1.3 billion metric tons of fertile soil each year (Teshome Tsegaw, 2007) out of which 1billion tone is from the highlands (Krauer, 1988). This is an indicator, as stated by

Gemechu Keneni (2007), for the low and declining agricultural production and continuing food insecurity and rural poverty in the country.

Jima Arjo Woreda is one of the rural Woredas of Ethiopia that inherited the physical and socio-economic situations prevailing in the country as stated above. The Woreda is known for its rugged topographic features, subsistence agriculture, significant deforestation, overgrazed land, and has significant soil loss by water erosion and is among the known Woredas in the country for its accelerated expanding degraded land (Geremew Bayata *et al*., 1998). Some farm lands were abandoned due to degradation and gullies were observed resulting in the reduction of farm land; plant roots were left out of cover (plate 1).

Plate 1: the soil being slashed away by Rill Erosion and Gully formation at Wayu Abayi PA
(Photo by Muleta: March/09)

According to the data obtained from the Woreda's Agriculture and Rural Development office and field survey, the amount of forest cover in the woreda is declining at an alarming rate. Natural (original) forest is hardly found in the area except limited patches along Didessa river course. The clearance and burning of this remaining forest is still continuing (plate 2).

Plate 2: The burning natural vegetation in Didessa valley *(Photo by Muleta: March/09)*

Most areas which were covered by the remaining forest during the previous government were converted to farm land few years a go and now some of these areas were made prone to extreme degradation. The expansion of farming on to the steep slopes has been observed while it is on the way of reaching an upper limit where it could no longer be expand further.

Besides removing the natural land resources, human land use practices were recognized as a driving force in initiating geo-environmental hazards. This is evidenced from the land slides occurred over the cleared and farmed hillside surfaces in Tibe Chafe P.A. (plate 3).

Plate 3: Land Slide occurred on Sept.11/2008 on the part of the cleared and cultivated forest land at the side slope of Tibe Ridge covering an area of about 1hectare *(Photo by Muleta: March/09)*

Therefore, it is of extreme importance to make assessment of the land use land cover dynamics and its implication to the soil resource of the area under investigation.

1.3. Research Objectives

1.3.1 General Objectives

The main objective of this study is to identify the impact of land use land cover change on soil resource and to delineate vulnerable areas to soil degradation by producing susceptibility maps using remote sensing and GIS technology.

1.3.2 Specific Objectives

The specific objectives are

- Identification of the extent and degree of land use/land cover change with respect to space and time
- Investigation of the implication and major consequences of land use/land cover dynamics in the study area
- Investigation of land use/land cover changes in different types of landscapes
- Estimation of actual soil loss for the Woreda using USLE
- Determination of the areal and temporal dynamics of land degradation

- To suggest the alternate land use and soil resource management for sustainable agricultural production

1.4. Significance of the Study

The most significant element in the process of economic development of any country involves appropriate land resource management. Ethiopia is primarily based on agriculture and hence adequate and sustainable agricultural production depends on the appropriate land resource management. In the study area, the current data shows an expanding land resource (specially, soil) degradation. If the current trend continues, the remaining soil will degrade and can in turn result in the degradation of the whole biophysical environment.

This study is, therefore, significant to understand the situation of land use/land cover and soil resource in the Woreda and helps to develop conservation strategies for future sustainable land use strategies. The result of the study is assumed to be significant for the land and administrative managers, policy and decision makers at different levels; agriculture and rural development officers and agents at the Woreda and/or other levels, environmental analysts, researchers and other concerned bodies to make land resource analysis.

1.5. Description of Materials, Data and Methodology

1.5.1 Description of Materials

Table 1: Summary of materials used

S. No	Types	Description	Source
1.	Instruments	GPS (Garmin72), Digital Polaroid Camera	Wollega University Personal
2.	Software	Arc GIS 9.2, ERDAS 9.1, ENVI 4.5, IDRISI 15 Andes, Visualization (3DEM)Software	AAU, Earth Science GIS Lab.
3.	Maps	Kebele Map of the Woreda Digital Soil Map Digital Geologic Map Topographic Map (Hard Copy)	CSA Min. of Agriculture &Rural Dev. EIGS, 1999 EMA, 1997

1.5.2 Data Description

The study used LandSat image data, Global Digital Elevation Model (SRTM), Climate data, Soil and geologic data, field data (GPS readings) and secondary data of the study area supported by interview and questionnaires.

1.5.2.1 Satellite Images

LandSat satellite images of MSS, TM, and ETM^+ were used to extract land use/land cover of the study area at various times.

Landsat Satellite Imageries

<u>LandSat MSS</u>: This is the oldest available data for the study area. MSS are optical mechanical scanners on board landsat satellites. They scan four spectral bands in the visible and NIR regions of EMS and have a ground resolution of roughly 80square meters (Dagnachew, 2005). MSS image of the area with path/row 182/054 acquired on 02 January 1973, obtained from Global Land Cover Facility (GLCF) online imagery portal has been used for the study.

<u>TM</u>: is the multispectral scanning system that record reflected /emitted electromagnetic energy from visible, reflective, middle and thermal infrared of the spectrum. They scan 7 spectral bands (0.45 to 2.35 µm) and have higher spatial (28.5 m) and radiometric (8 bit) resolutions than MSS. They are applicable for different feature identification (Lillesand and Kiefer, 2000). For the study area, the image of a single scene with path/row 170/054 acquired on 03 August, 1986 by TM sensor on board LandSat 5 was used as a mid study period. It is also obtained from the GLCF online imagery portal.

<u>ETM^+</u>: is a sensor of LandSat7 satellite that observes the earth and is capable of capturing scenes without cloud obstruction. It scans 7 multi spectral bands (0.45 to 2.35 µm) and has higher spatial (28.5 m) and radiometric (8 bit) resolutions than MSS. They are applicable for different feature identification. It also scans thermal band in the range 10.4 – 12.5 µm EMS with 60m spatial resolution. ETM^+ also has an 8^{th} panchromatic band with 15m spatial resolution (Lillesand et al, 2004). For the study, the image with 170/54 path/row acquired on 02 May 2001 has been obtained from the online archive of the GLCF.

1.5.2.2 Global Digital Elevation Model (SRTM)

All elevation data and subsequent derivations like slope, aspect, contour, hill shade and contours are derived from DEM acquired from SRTM. SRTM represents an elevation map from the NASA Shuttle Radar Topography Mission datasets. It covers between latitudes of 60^0 N and 56^0 S and is available at several European and North American data providing portals. SRTM data has a horizontal ground resolution of 3 arc seconds (90 meters) and represent elevation in meters. SRTM data does not require any ground control points to map inaccessible areas (http://www2.jpl.nasa.gov/srtm). For the study area SRTM data extending from N07E036 to N09E037 of the year 2000 has been obtained.

1.5.2.3 Climate Data

The study used rainfall and temperature data of the study area for the period 1988-2006 obtained from NMA. This is because climate element (the rainfall amount, intensity and distribution) indicate its power or aggressiveness to cause soil erosion and degradation (Krauer, 1988). How ever, it is important to note that climate or weather data collected from meteorological stations literally represent only the measurement of the location where the instrument is installed. Such recorded data can neither exactly represents the whole area nor evenly distributed across any area. Therefore, the known (observed) values of point data should be extended for locations with no observations. This can be done through interpolation techniques. There are generally two interpolation techniques (deterministic that use mathematical functions and geostatistical or stochastic that use both statistical and mathematical methods of interpolation) (Johnston *et al*, 2001). For this study, geostatistical interpolation technique has been employed using Arc GIS 9.2 sofware.

1.5.2.4 Soil Data

Soil property indicates the state of the soil and hence its erodibility and degradation is partly owing to the characteristic of the soil. Thus, the soil data of the study area has also been used. It was extracted from the digital soil data of Ethiopia obtained from the MoA & RDE.

1.5.2.5 Field Data

Land use/land cover mapping without field investigations is prone to errors. Field investigation is required either to collect training data for digital classification, for ground verification or validation and is part and parcel of applied remote sensing. Therefore, GPS readings were collected from the field. Moreover, field visits were made and allowed an overview of the of the study area as a whole, the cover management and supporting practice of the area. It also helped to identify the major land use/land cover types of the area for subsequent supervised classification.

1.5.2.6 Data Collected from Interview

Land use/land cover dynamics is strongly linked with the socio-economic aspect of a given area. Thus, interview questions were prepared and presented for the study area's agricultural and resource managers and sample community members. Two experts of the Woreda's Agricultural and Rural Development office were interviewed. Assuming agroclimatic zones with similar character possess similar socio-economic aspect, farmers of the Woreda have been grouped into three based on the agroclimatic zones. As the data to be obtained from the sample members is a support for the remotely sensed data, 45 total samples, were 15 samples from each agroclimate has been determined. Thus, from each agroclimatic zone, 15 individual sample farmers that possess the required information were selected by available /comprehensive/ purposive sampling technique. This has been carried out based on the information obtained from the Woreda's Administration and Agricultural Development Offices. The responses obtained from both the experts and sample farmers were analyzed in relation to each other and with the remotely sensed and GIS data.

1.5.2.7 Secondary Data

Secondary data have been gathered from different sources. Background information of the study area has been obtained from some previous works in the area. Rivers, various road category and towns have been manually digitized from the 1:50,000 scale topographic map of the area obtained from EMA. Geological data has been extracted from the geological data of Ethiopia prepared by EIGS. Kebele boundaries were acquired from CSA.

1.5.2.8 Methodology Description

LU/LC is linked with both physical and socio-economic conditions. Hence, both data were used in the study. In order to obtain the socio-economic aspect of land use data, field surveys and interviews supported by investigation of archival materials were implemented. For the physical land use/cover and soil degradation data, remote sensing and GIS techniques were implemented. Digital satellite images were processed, classified and analyzed using both ERDAS 9.1 and ENVI 4.5. The classified data (in to each category of land use/ cover) were further analyzed for change detection and generation of soil erosion parameters. Terrain data (elevation and slope) were generated from SRTM data after being patched for the anomalies (unfilled pixels) using 3DEM visual software and further processed using Arc GIS 9.2 software spatial analyst tools. Soil and rainfall data were generated to obtain factors of soil erosion using ArcGIS 9.2 software. Multi-criteria evaluation techniques were employed on land use/cover change and soil degradation vulnerability analysis through pair-wise comparison in the IDRISI 15 Andes software and weighted overlay has been made in the ArcGIS 9.2 environment (Fig. 1).

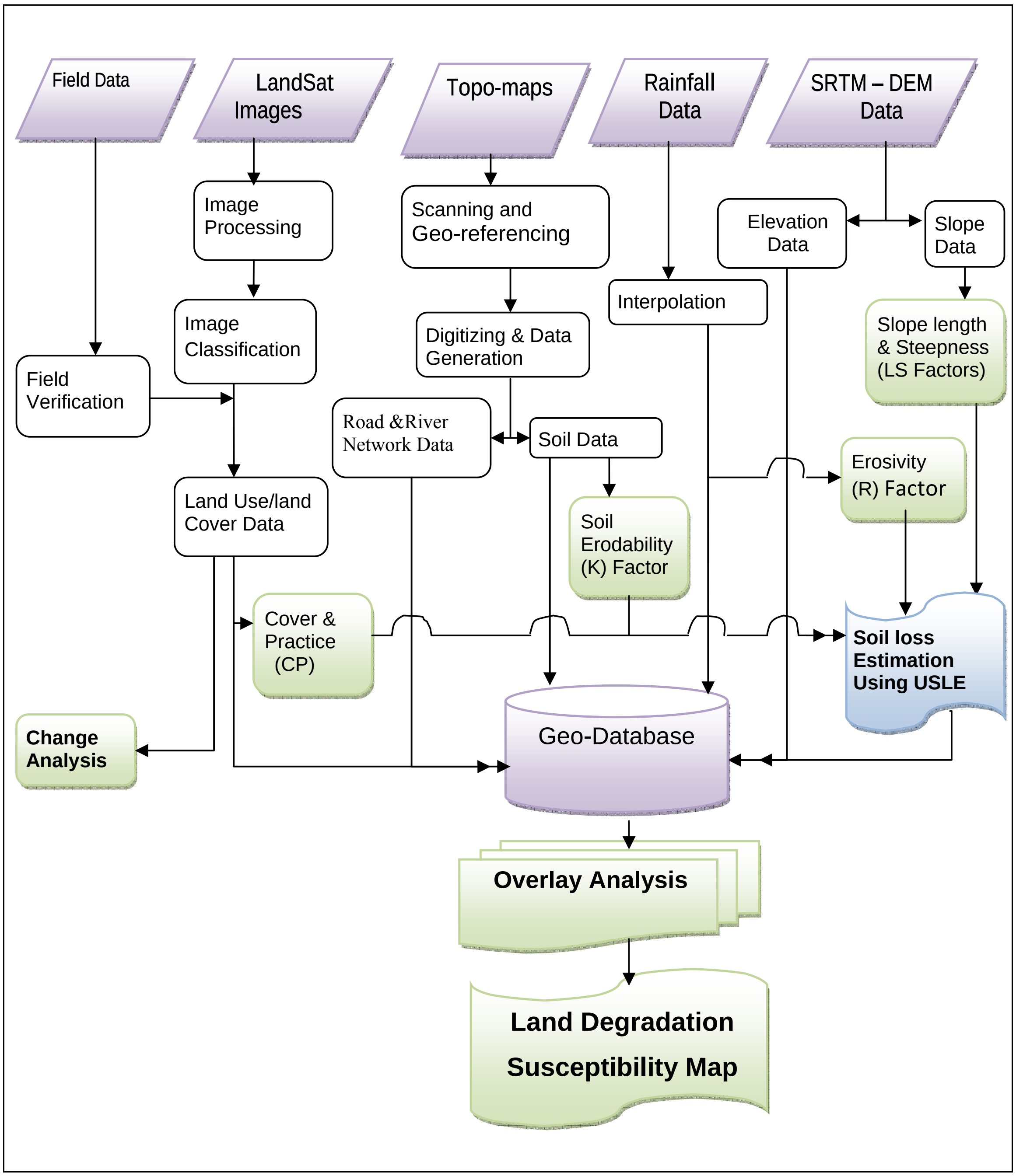

Figure 1: GIS methodology flow Diagram

2. LITERATURE REVIEW

2.1 Land Use/Land Cover Dynamics and Soil Degradation

2.1.1 Land Use/Land Cover Dynamics

Land use and land cover are not equivalent but they are connected and function as hybrids. While land use is the human employment of the land, land cover indicates the physical state of land. The change of human use of land is associated with change in the physical states of land cover. Although land use/cover change are caused by both natural and anthropogenic factors, most land use/land cover changes and dynamics are attributed to the interaction between human continued demand for land products and the capacity of the land and the environment to sustain the demand (Meyer and Turner, 1998).

Many research studies indicated as land use/cover dynamism is primarily associated with agricultural activity. Wright (1993) and Botkin and Keller (2005) described agriculture and settlements as the major ways in which people have changed natural landscape. Three most important human factors were recognized as change agents of land use/cover. The first is the need to provide food for rapidly growing population. This necessitates the expansion and intensification of agricultural land. The second is the provision of land for the landless in order of self sufficiency to exist and the third is to provide land for multinational companies to carry out agribusinesses.

The modification and/or destruction of natural land resources can lead to land degradation. This has been pointed out on the works of Krauer (1988) and Teshome Tsegaw (2007) as land degradation is the reduction of land productivity.

2.1.2 Soil Degradation

Soil is a vulnerable and exhaustible resource and once depleted or badly damaged its replenishment is difficult, slow and expensive (Chandra, 1990). The interventions in the natural condition of soils inevitably create a considerable threat to the soil. Humans through alteration and reducing the vegetation cover naturally associated with the soil can contribute to nutrient and fertility depilation, carbon and biodiversity reduction and deterioration of the soil's physical properties and hence accelerate soil erosion. Soils of mountainous environments (as Ethiopian highlands) are very sensitive to such intervention.

2.1.2.1 Soil Erosion

Soil erosion is the most common and dangerous ecological process that degrades soils. Although water and wind are both agents of soil erosion, wind erosion is not generally a problem of any significance in the humid areas. Almost the entire occurrence of undesirable soil erosion in such areas is associated with water runoff.

Studies made by several investigators indicate as erosion is a natural phenomenon, but man's reshaping of the natural environment has accelerated the event. As indicated by Wright (1993), Morgan (1996) and Taffa Tulu (2002), man can make the soil a natural focus for overland flow and soil erosion. Removing the natural vegetations, farming sloppy and fragile areas inappropriately and compacting the soil are some of the ways in which human activity make the soil prone to accelerated erosion. When these combined with misaligned policies and unclear property rights it can worsen the situation (World Bank, 2006). The net effect is loss of productivity and land abandonment.

The level of soil erosion reflects its impact on soil resources. As examined from the works of Morgan (1996) and Taffa Tulu (2002), splash erosion, sheet erosion, rill erosion and gully erosion yields many varied impacts. The gradual development of erosion from the very subtle splash erosion in to gullies that almost always associated with accelerated erosion indicates the severity of soil erosion.

Different factors determine the susceptibility of a soil to erosion. As investigated from studies made by Hurni (1986), Krauer (1988), Ellis and Mellor (1995) and Morgan (1996), soil's inherent property, climatic factors, terrain characteristics and the type of land cover were determined as significant factors and can indicate the level of soil erosion over a given area. The structure, depth, organic matter and clay mineral content, water retention and transmission capabilities of soils have implications on the level of soil erosion. Climatic variables (rainfall and wind velocity, temperature, humidity and radiation receipts) by causing erosion in different ways can determine the erosive power of erosion. This is one of the reasons why the visible impacts of soil erosion are so much more pronounced in the humid tropics. Slope gradient, aspect, shape and length of a field are the terrain characters that can strongly influence the amount of erosion. The existing vegetation cover is also a significant factor. As stated by Clark II et al, (1985) and Wright (1993) vegetation cover affects soil erosion in three ways. First, their canopy protects the soil surface from the impact of falling rain drops. Secondly, they slow down surface flows and thirdly they can increase the amount of infiltration.

2.1.2.2 Soil Erosion Assessment and Modeling

Field studies for soil erosion assessment are expensive and time-consuming. With limited resources, an effective way of determining the process of soil erosion is the use of models. A model is a mathematical expression of the relationship and interrelationship of major governing factors of a system (Moldenhauer and Foster, 1981).

Several soil erosion models were developed. But the most widely and frequently used soil loss model is the Universal Soil Loss Equation (USLE) (Moldenhauer and Foster, 1981; Harline and Berardi, 1987 and Morgan, 1996). It is used to predict long term mean values of soil erosion that would generally result from sheet and rill erosion on agricultural plots. It has been considered as a good predictive tool by different researchers, planners and consultants since it considers ranges of parameters that significantly influence soil erosion.

As indicated in the studies of Krauer (1988), Gunten (1993) and Morgan (1996), the equation considers factors of climate, soil, topography, land cover, and human interaction over the landscape and thus estimates soil loss from the multiplication of rainfall erosivity, the soil erodability, slope gradient, slope length, cover management and erosion management practices.

The USLE model at the beginning was specifically developed for USA with the natural conditions of temperate zones as a design tool for conservation planning. Due to its good predictive ability and comprehensiveness by allowing more detailed consideration of farming practices and topography and its simplicity, the equation has been applied to conditions beyond USA through modification of some of its factors (Morgan, 1996).

In Africa, several efforts have been made to apply USLE model to the conditions in specific localities by adopting some of the parameters to the local conditions. As cited in Krauer, (1988), Hurni, (1985), adapted the USLE model to the Ethiopian conditions by modifying some of the factors based on experiment outputs. Using this adapted model factors, various soil loss assessments have been conducted in Ethiopia. Girma Urgecha (2005) and Tsegaye Berkineh (2007), were applied the model and obtained the actual soil loss over different parts of the country.

2.2 Overview of LU/LC Dynamics and Soil Degradation in Ethiopia

At the turn of 20^{th} centaury, 40% of Ethiopia's land surface had been covered with forest (Solomon Abate, 1994). Since then, the natural vegetation covers were diminished caused by various land uses; forests were sharply reduced and croplands were expanded. UNEP (1983) cited in Krauer (1988) evidenced as the forest cover of Ethiopia prior to 1960s was shrunken to 16% coverage at the time the study conducted. Recent studies conducted also indicate the diminishing trend of forest resources in the country. This can be realized from the work of Taffa Tulu (2002), as the forest resources of Ethiopia are concentrated on 3% of the area which are located in the South western highlands.

Change of land cover of Ethiopia is directly attributed to the history of settlement and population growth. The increasing population needed the production of more food to meet the raising demand. This forced the conversion of areas covered with natural vegetations including the steep slopes and fragile areas to farm and settlement. The subsequent increasing demand for fuel and constructional wood further extended the chance of the natural vegetation removal (Solomon Abate, 1994).

The change of land use/cover evident in the country inevitably made the soils prone to degradation. Krauer (1988), estimated at the time as more than 50% of the country's land area has a problem of sever soil degradation and this is predominant where the natural vegetations (particularly forests) have been destroyed long a go. This fact is also pointed out by Mesfin Abebe (1998) as the soils of some parts of Ethiopia (particularly that of the highlands) degraded to extreme level.

Soil erosion is one of the major factors of soil degradation in Ethiopia (Hurni, 1986; Krauer, 1988, Gunten, 1993 and Mesfin Abebe, 1998). Various estimations made pointed out as the rate of soil loss in the country is high and increasing at an alarming rate. Hurni (1988) cited in Gunten (1993) estimated the annual soil loss by erosion as 12t/ha. The later study made by Hurni (1993), cited in Taffa Tulu (2002), raised the annual soil loss due to erosion from croplands of Ethiopia to 42t/ha where maximum loss (300t/ha) is recognized over the highlands. The recent study conducted by Berry (2003) cited in Girma Urgecha (2005) further raised the rates of erosion in the country as 130 t /ha/year for crop lands.

Throughout Ethiopia, except the desert zones of Ogaden and Danakil plains, the soil is subject to water erosion under the action of rainfall (Krauer, 1988). This is owing to the rugged topography, the brief but extremely heavy rainfall and the over centuries inappropriate land use practices (Chandra, 1990 and Solomon Abate, 1994).

2.3 Remote Sensing and GIS Technology in Land Use/Land Cover Dynamics and Soil Degradation Assessment

Proper organization and monitoring of land resources requires not only an understanding of the spatial and temporal patterns of resources but also insight in to the spatial and temporal process governing their availability. Such analysis demand timely repetitive and continuous spatial data. Ground surveying of such data is difficult and often expensive and such problem is a significant feature of developing countries with agricultural economy like Ethiopia (Wall et al., 1982).

Land use/land cover and soil degradation study requires analysis of an interlinked physical and socio-economic factors. With in such an interlinked environmental system, modeling and predicting uncertainty of the factors can help us to manage land resources appropriately. This in turn requires analysis and manipulation of large volume of different kinds of datasets with respect to their geographic location. It is GIS and its data source (remote sensing) technology that can manipulate such interlinked system datasets (Vieux, 1995).

Different researches conducted in Ethiopia on land degradation proved the capability of remote sensing and GIS in identifying hazard prone areas. Yodit Teferi (2005), applied integrated Remote Sensing and GIS techniques to evaluate the extent and cause of land degradation and land slide in southern Ethiopia and noted as land use/cover and soil are among the major factors of land degradation. Meeraph Habtewold (2006) applied Remote Sensing and GIS in identifying land degradation vulnerable areas and the governing factors. Accordingly, the sensitivity of each land use/land cover class to degradation has been calculated using GIS.

2.4 GIS Based Multi-Criteria Decision on Land Use/Cover Change and Soil Degradation Vulnerability

Land degradation is obviously related to the interaction of multiple systems with difficult and complex factors. Understanding the interaction, the process and level of the influence of each factor system helps to determining the feature trend of the land resource at hand. This calls for the application of multi-criteria analysis. MCE is one of the most appropriate techniques to handle spatial problems and integrate different data layers with heterogeneity and certain levels of uncertainty. It involves a set of mathematical tools and methods that allow the comparison of different alternatives based on the comparative importance of each criterion (http://idrisigis.wordpress.com).

GIS, using multi criteria analytical facilities and pair wise comparison techniques, help to solve geographical related problems. GIS based MCE is most commonly achieved by one of the two procedures. The first involves Boolean overlay whereby all criteria are reduced to logical statements of preference and then combined by means of one or more logical operators: intersection (AND) and union (OR). The second is the weighted linear combination (WLC) where continuous criteria (factors) are standardized to a common numeric range, and then combined by means of a weighted average (Eastman, 2006).

In many spatial based research activities, GIS based multi-criteria evaluation has been proved of great importance to identify and solve spatial problems. As indicated on the work of Yodit Teferi (2005), multi-criteria evaluation techniques provided a series of pair-wise comparisons on the relative importance of factors of land degradation. Based on the weight values of the factors derived from the pair-wise comparison, land use/land cover has been signified in aggravating land degradation. Meeraph Habtewold (2006) also used the procedure of WLC that considers all data layer value depending on their weight to assess land degradation activity. Accordingly, susceptible areas were clearly identified. Fite Getaneh (2008) also employed GIS-MCE and appropriately identified susceptible areas to forest degradation.

In conclusion, land use and land cover are connected and many studies indicated as the land use/cover dynamics are caused by human agricultural activities. It has been investigated that the modification and destruction of the natural land resources could lead to soil erosion and the then degradation. As stated by many research activities, the land use practices in Ethiopia have changed much of the natural land cover of the country. This in turn made the soils of the country, particularly over the high land, prone to erosion and degradation. The application of remote sensing and GIS technique has been proved significant in assessing and monitoring the land resource degradation.

3 BACKGROUND OF THE STUDY AREA

3.1 Physical Setup of Jima Arjo Woreda

3.1.1 Location and Accessibility

Jima Arjo is found in East Wollega Zone of Oromia region 379Km west of Addis Ababa. The Woreda share's boundary with Leka Dulecha, Guto Wayu, Nunu Kumba and Bedelle (Ilubabor Zone) Woredas in north and northwest, north, east and south and south west, respectively. According to the current structure, it has 21 Kebeles (peasant associations). The Woreda is bounded by $8^0$33' to $8^0$55'N latitudes and $36^0$22' to $36^0$44'E longitudes and has a total area of 773 sq Km (77,258 hectares (Fig. 2).

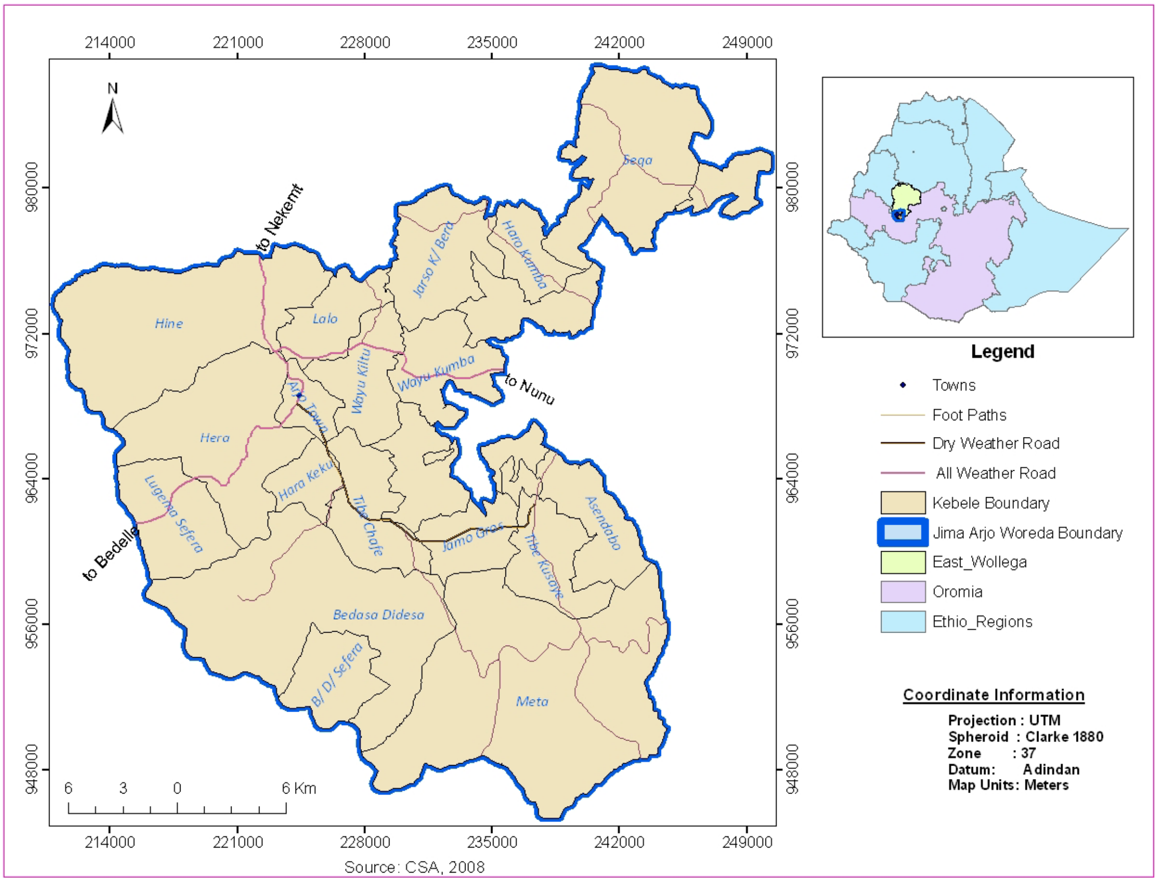

Figure 2: Map of the study area

The Woreda is crossed by the main road running from Nekemte in the North to Bedelle in the southwest and a recently constructed all weather roads that join Jima Arjo with Nunu Kumba Woreda in the East. During dry season, it is possible to access all peasant associations at least with motor bicycles.

3.1.2 Climate

The Woreda falls in between the traditional wet Kolla and wet Dega climates (Fig. 3). From the total area of the Woreda, 4.5% falls in Wet Kolla (Tropical), 80.7% is Wet Weyna_Dega (subtropical) and 15% falls in Wet Dega (temprate) Climates.

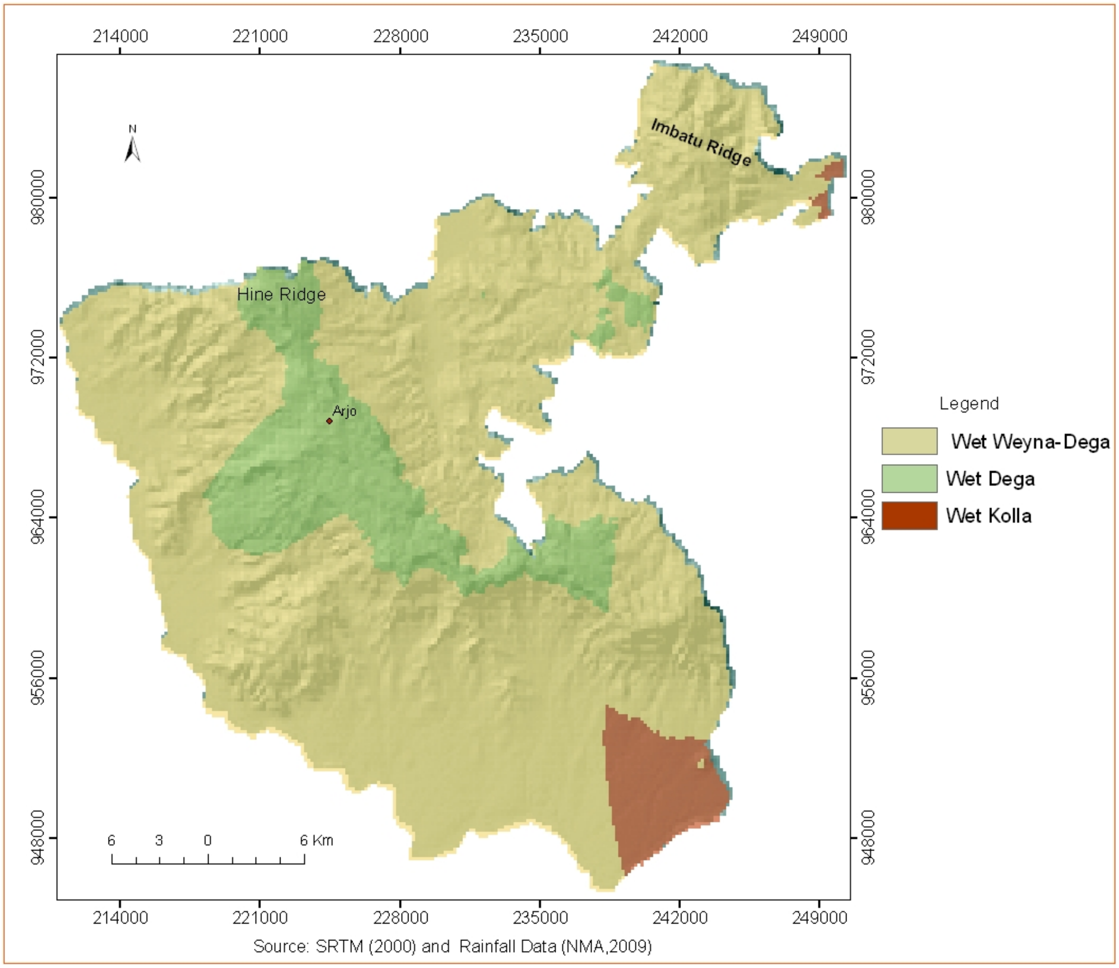

Figure 3: Agro-climatic zones of the study area

3.1.2.1 Rain Fall

The mean rainfall based on 19 years record (1988 – 2006) is 1855.3 mm. Even though the intensity varies, almost all months receive rainfall. April-September are months with high rainfall. The lowest mean monthly rainfall (14.1mm) was recorded in the month of January while the highest 332mm recorded in August (Table 2).

Table 2: Mean Rainfall at Arjo Station (1988 – 2006)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
RF (mm)	14.1	18.9	90.5	111.61	203.3	307.7	320.23	332	252.1	133.93	38.6	32.33	1855.3

(Source: NMA, 2009)

Table2 and Fig. 4 indicate that rainfall in the study area is unimodal with monthly rainfall rising steadily from March to a peak at August and then descends gradually to the month of December. Months from May to September are when the area receives more rain (76.3% of the total rain of the area).

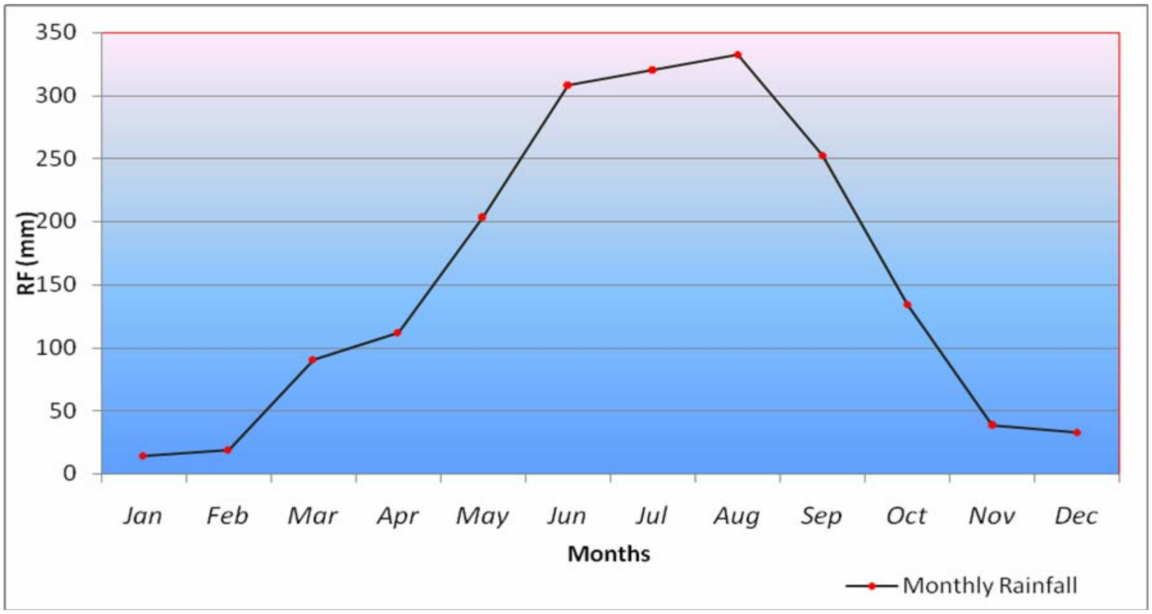

Figure 4: Monthly rainfall distribution graph at Arjo station

The rainfall distribution recorded over the 19 year period showed variations that range from 1353.6mm in 2002 to 2360.7mm in 2004 (Fig. 5).

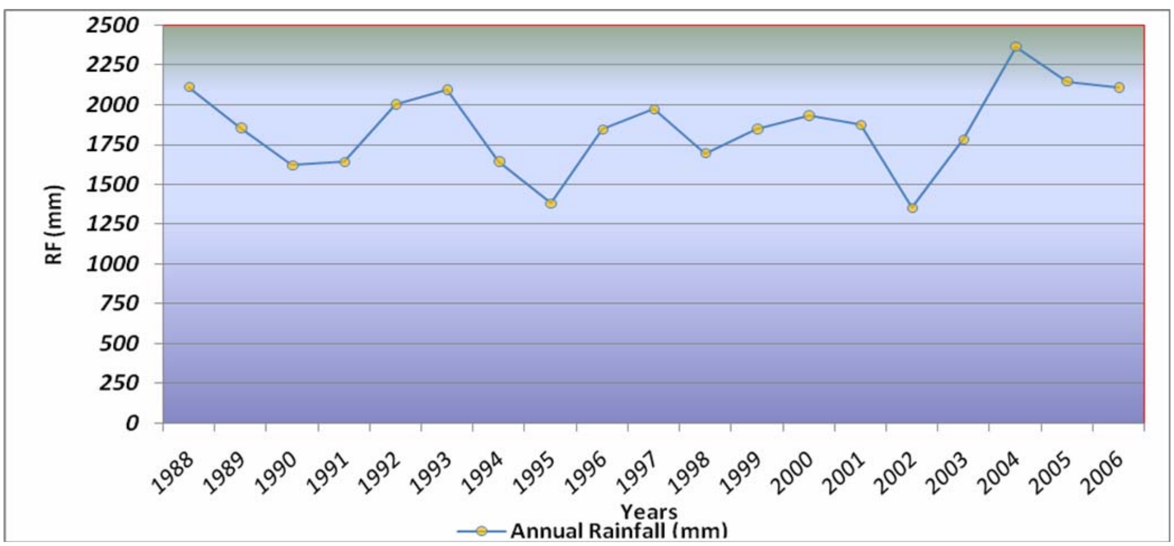

Figure 5: Rainfall and erosivity trend at Arjo station

3.1.2.2 Temperature

Temperature data for the years 1988 – 2006 indicate that the temperature of the study area ranges 10^0C to 23^0C. The average annual temperature is $\simeq 16^0$C. The hottest and coldest months are March and July, respectively (Table 3). The annual range of temperature in the area is less than the diurnal range.

Table 3: Monthly Temperature at Arjo Station (1988 - 2006)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Max T^0C	22.2	22.9	23.5	22.7	21.9	19	17.4	17.6	18.8	20.3	20.7	21.9	20.8
Min T^0C	10.8	11.5	12.4	12.2	11.5	10.5	10.1	10.3	10.6	11	11.1	10.9	11.1
MeanT^0C	16.5	17.2	18	17. 5	16.7	14.8	13.8	14	14.7	15.7	16	16.4	15.9

(Source: NMA, 2009)

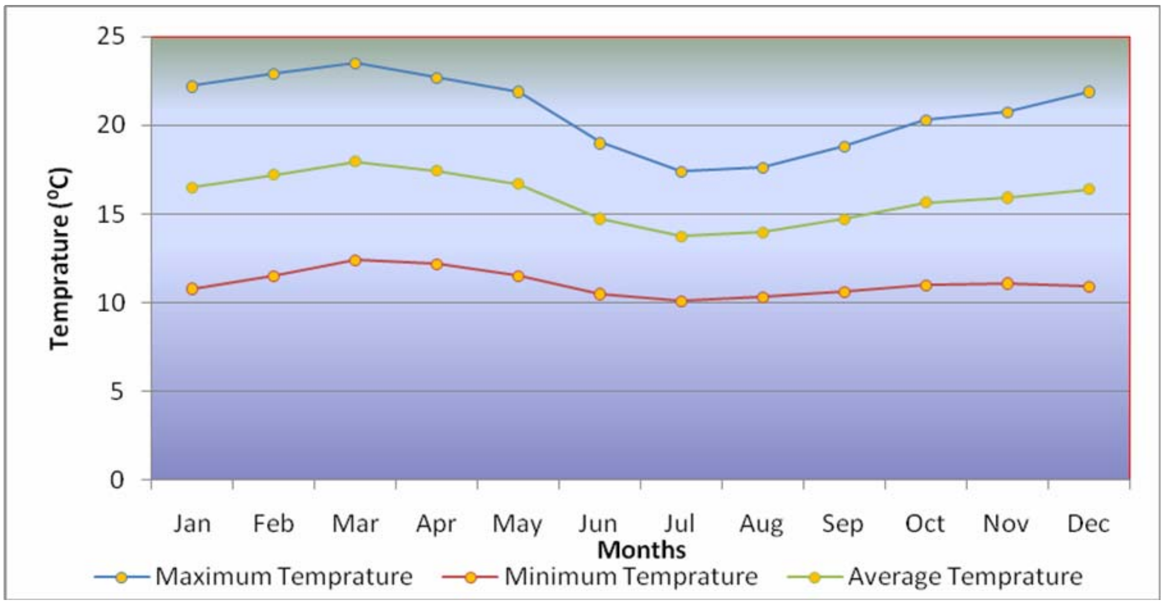

Figure 6: Monthly temperature graph at Arjo station

3.1.3 Landform and Drainage

The physical landscape of Jima Arjo is quite diversified. The major topographic features of the area are composed of hilly, flat to undulating rugged topography, plain, plateau and valley with altitude variation from 1264 at Didessa valley floor in the south west to 2599 m a.s.l. at Hine ridge at the North western part of the area (Fig. 7).

Some of the relief forms identified in the landscape of the area are a well defined conical or oval hills dissected by rivers , moderately steep to very steep hill side slopes, gently slopping flat terrains, deeply incised “V” shaped valleys and steep valleys and gorges.

The general slope distribution grouped by slope class is given in fig. 8. A substantial percentage (67.2%), of the area has a general slope of over 8% and the slope that ranges from relatively gentle to less steep (<8%) covers 32% of the area.

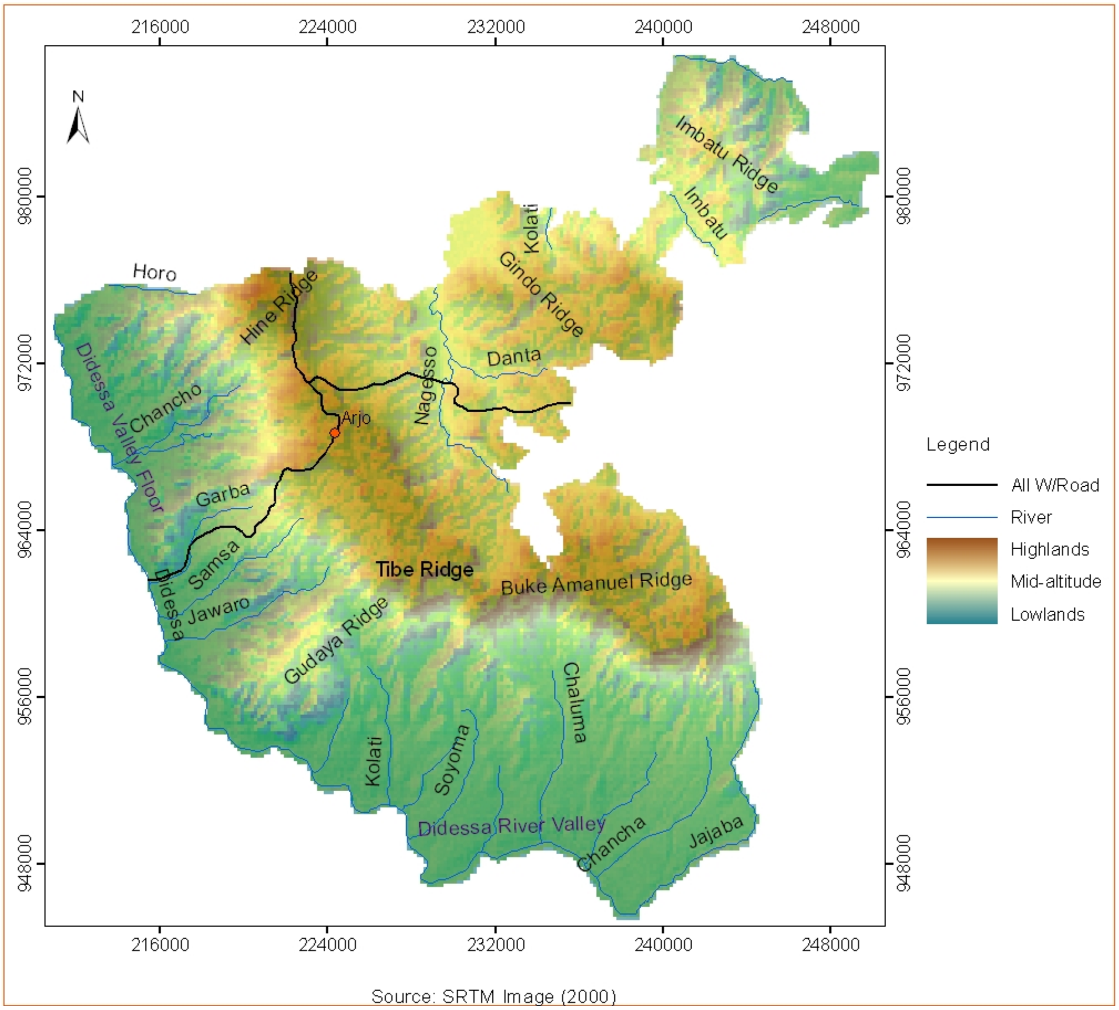

Figure 7: Physiographic units of Jima Arjo Woreda

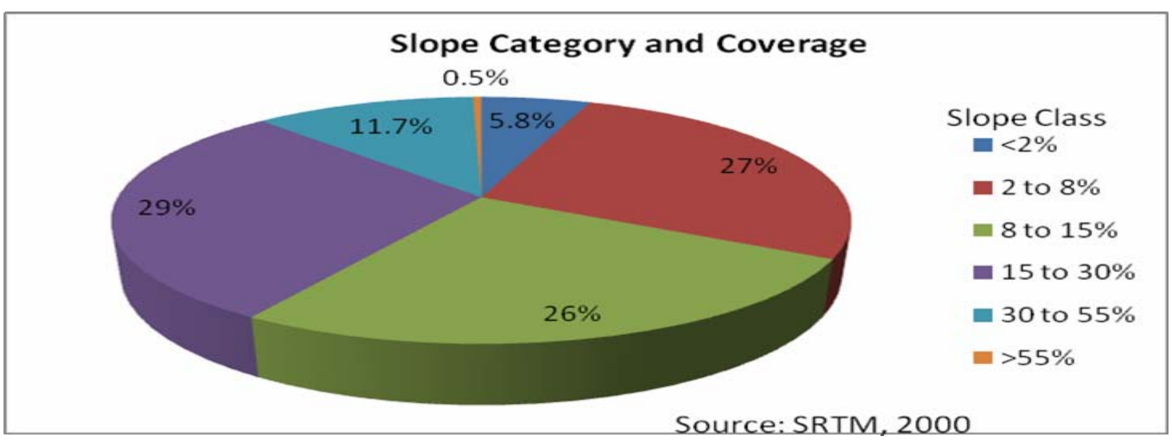

Figure 8: Slope category of the study area

According to the agro-climatic classification of Ethiopia by MoA and RDE et al., (2005), the relief/land form of the study area can be grouped in to three major physiographic units based on their elevation. The lowlands with <1500m a.s.l, mid altitude with 1500 – 2300m a.s.l and highlands with >2300m a.s.l with 30%, 58% and 12% coverage, respectively (Fig. 9).

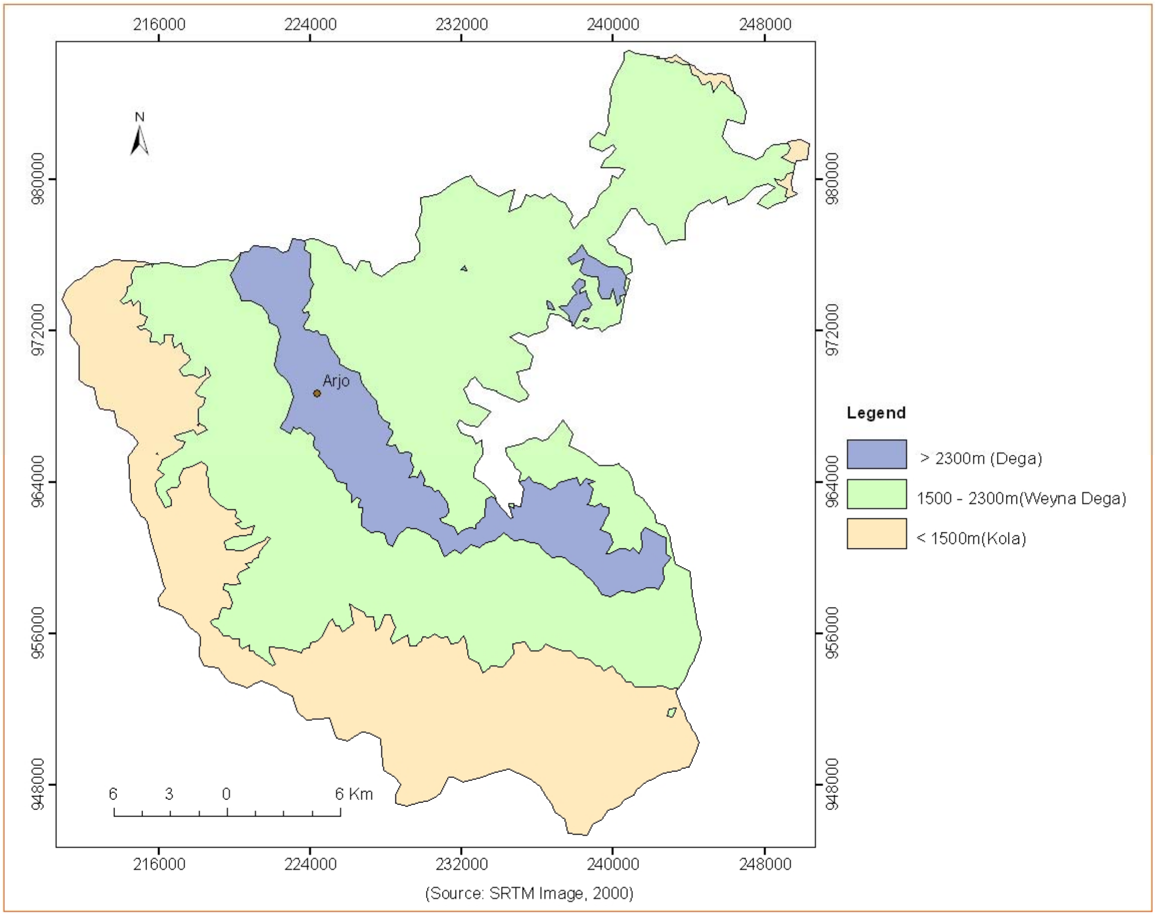

Figure 9: Slope category of Jima Arjo Woreda

The Woreda is drained by many intermittent and a number of relatively principal rivers (Fig. 7). A range of highland from Hine (North west) to Buke Amanuel (South east) through Arjo town, forms a watershade for rivers flowing to different directions.

The drainage of the study area is characterized by radial pattern in which most of the streams flow out ward from the centeral highland.

3.1.4 Geology

The largest part of the study area is constituted by the Precambrian basement rocks that blongs to the Alghe group which constitutes high grade genesis and pretectonic granites (Mengesha Tefera *et al*., 1996). The Northeastern part of the area constitutes more diverse geological set up where the Precambrian basement overlain by the Mesozoic Adigrat sandstone or directly by the Oligocene-Miocene age of Ashangi group volcanic rocks (Fig. 10). There are also isolated exposures of early Palaeozoic granitic plutons and Quaternary basalts in the northern and eastern extremities of the study area, respectively.

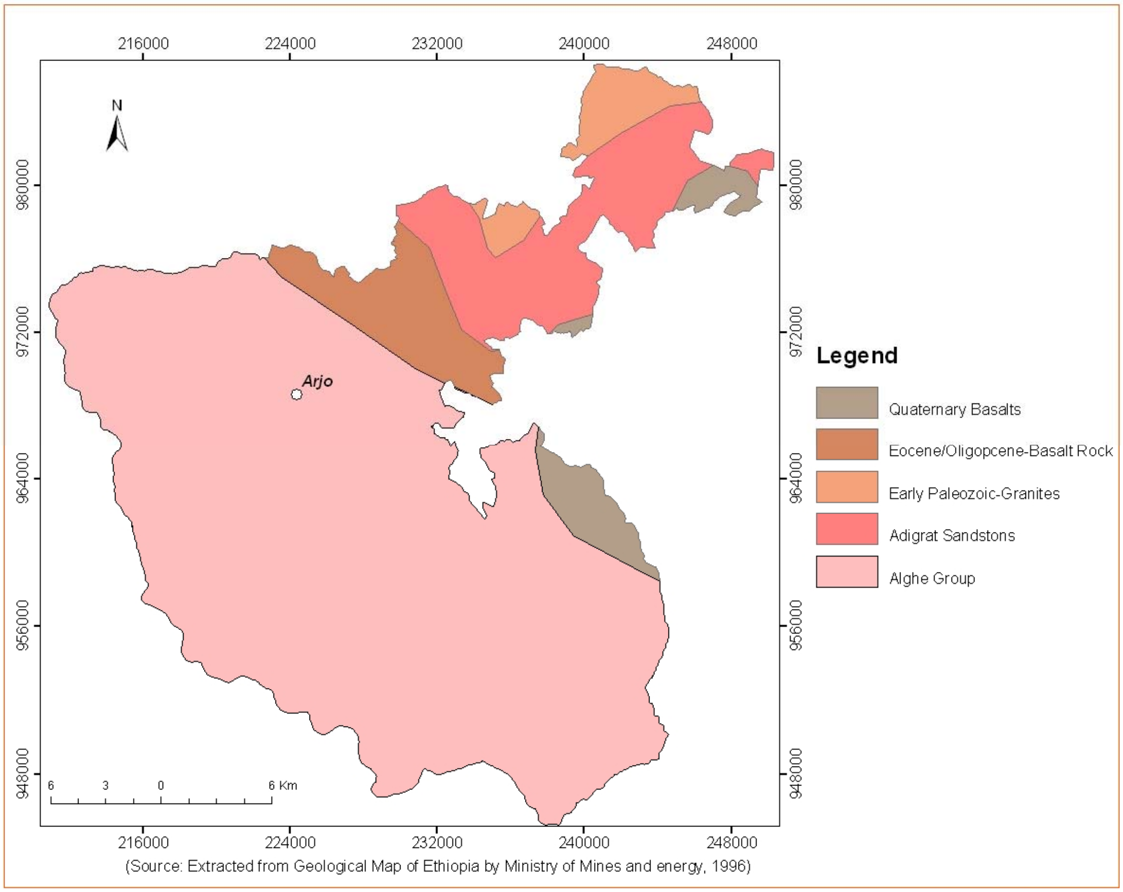

Figure 10: Lithological map of the study area

3.1.5 Soil

Jima Arjo possesses different soil types associated with the geomorphology and the geology of the area (Fig. 11). The steep side slopes and escarpments of mountain plateau and gorges have very shallow soils. Soils of moderately stream dissected plateaus with flat to gently undulation are deep to very deep, well drained, clay loam to clay textured soils. The Nagesso depression and some pockets of Didessa valley have heavy clay textured vertisols. Most areas of Didessa valley and foot slopes of Imbatu ridge have silty clay loam, gravely clay and sandy loam soils (Geremew *et al.*, 1998).

According to the extracted digital soil data obtained from MoA and RDE, the area has 4 major soil classes based on FAO/UNESCO soil classification system. They are dystric nitisols, pellic vertisols, dystric gleysols and orthic acrisols.

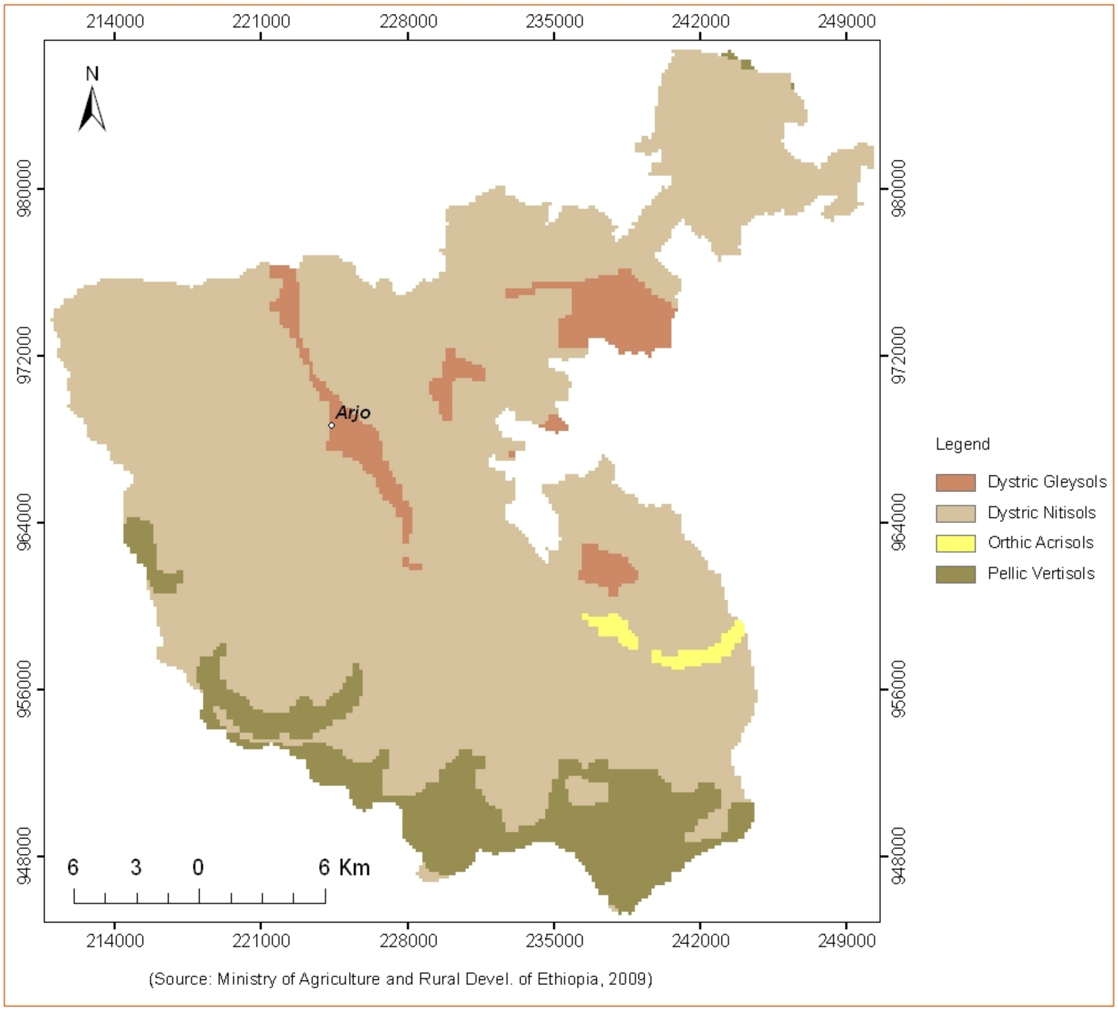

Figure 11: Soil map of the study area

3.2 Land Use/Land Cover

From the relatively recent (2001 year) Landsat image data, the land use/land cover of the area possesses seven land use/cover units: the farm land, dense forest land, degraded forest, wet land, grass land, open wood land and bare land (Fig. 12). The lowlands around Didessa are covered with some reverin forests, sparse vegetation and woody grasses. Different patches of the highlands are covered with man made and very little natural vegetations of different species. Through out the study area, there are very scare remnants of the original natural vegetations mostly found in few pockets of Didessa valley. The distribution of tree species varies from place to place in the Woreda. The vegetation of the area composes some scattered trees, bushes and shrub species over the high lands.

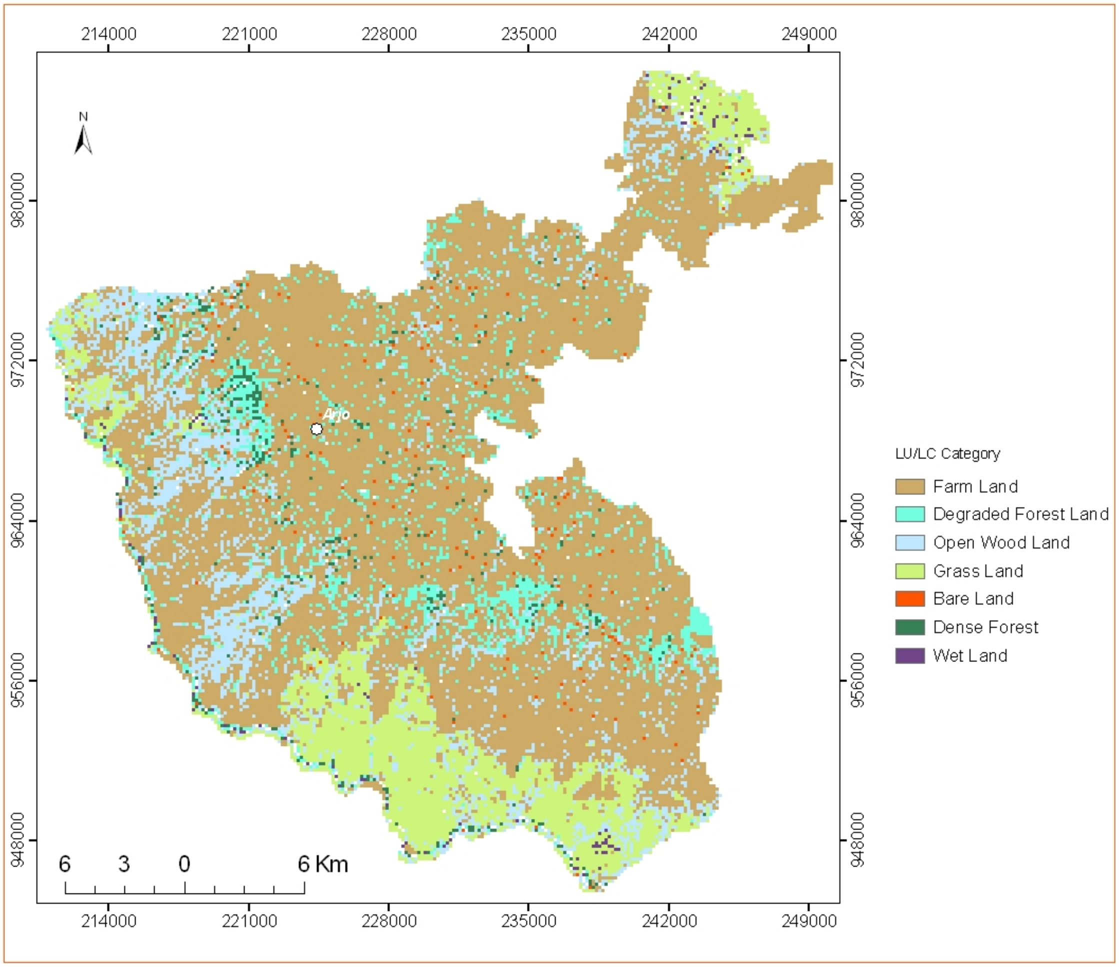

Figure 12: Land use/cover map of the study area

3.3 Socio – Economic Structure of Jima Arjo Woreda

3.1.1 Population Size and Distribution

According to CSA (2008), the size of the population of J/Arjo Woreda is 88,279 and out of this the rural population is 77,916 (88.3%), and the remaining 11.7% lives in the town of Arjo. With this population statistics, the Woreda has a crude density of 114.2 persons per sq. Km which is by far greater than the country's crud density (based on the recent statistics and Ethio-boundary area, it is 65.24 persons per sq. km).

3.1.2 Economic Activity

Agriculture is the dominant sector and biggest employer of the economically active population in the Woreda (more than 88% of the total population). The farming system in the Woreda is a mixed agriculture type (grain crop and livestock production). Agriculture in the Woreda is characterized by extremely small holdings that are private farmers, dispersed cropland holdings with traditional farming.

4 DATA ANALYSIS

4.1 Land Use/Land Cover Data Analysis

The major information of land use/land cover types of the study area at different time periods has been extracted from Landsat satellite imageries.

4.1.1 Digital Image Processing

The digital image data of the MSS, TM and ETM^+ has been employed to assess land use/land cover of the study area. These image data which were stored as a two dimensional array of pixels that corresponds spatially to the area under investigation has been processed (rectified and restored and enhanced) and Classified.

Image rectification and restoration is a technique of correcting image data for distortions introduced to the image data during the acquisition process to create a more faithful representation of an area. Image rectification and restoration normally precedes any further manipulation and involves geometric and radiometric and/or noise removal and correction (Leica Geosystems, 2005).

4.1.1.1 Orthorectification and/or Restoration and Enhancement of the Images

I. Orthorectification and/or Restoration of the Images

The images were found originally orthorectified by the supplier. How ever, the image of the 1986 TM has cloud cover since the image has been recorded in August, a summer month over the area. Therefore, some haze compensation techniques were employed on the image. In addition to this, reprojections to Clarke 1880/UTM zone 37N were made to all the images since most of the national map products of Ethiopia use this projection (Bedru Sherefa, 2006). Following this, the image data of the study area has been extracted based on the shape file data obtained from CSA.

II. Image Enhancement and Visual Interpretation

To aid the visual interpretability in determining major land use/land cover types of the images of the area under investigation, histogram equalizer, which is one of the radiometric enhancement techniques, was employed. It is a contrast enhancement technique which subdivides the original image data DN in to equal spacing and stretch it by considering the frequencies of DN's. Tasseled cap transformation, one of the Spectral enhancement techniques, that defines vegetation by combining mathematically different bands (Leica Geosystems, 2005) was also employed to the image data. RGB to IHS conversions and color combination of the original image data have also been made. With respect to color combination, different image bands need to be combined since a single band image is generally black and white and may not be discriminated by the human eye (Dagnachew Leggese, 2005). Hence, both TCC (when bands 1, 2 and 3 /or blue, green and red bands are combined through transmission in blue, green and red filters) and FCC (combination of possible color filters other than the case in TCC) were produced and analyzed. The techniques optimized visibility of the data structure of interest in each case and made the image visually and spectrally more interpretable. As can be seen from the samples (Fig. 13) below, land use/land cover category of the study area is visually interpretable more after enhancements made to the original image data.

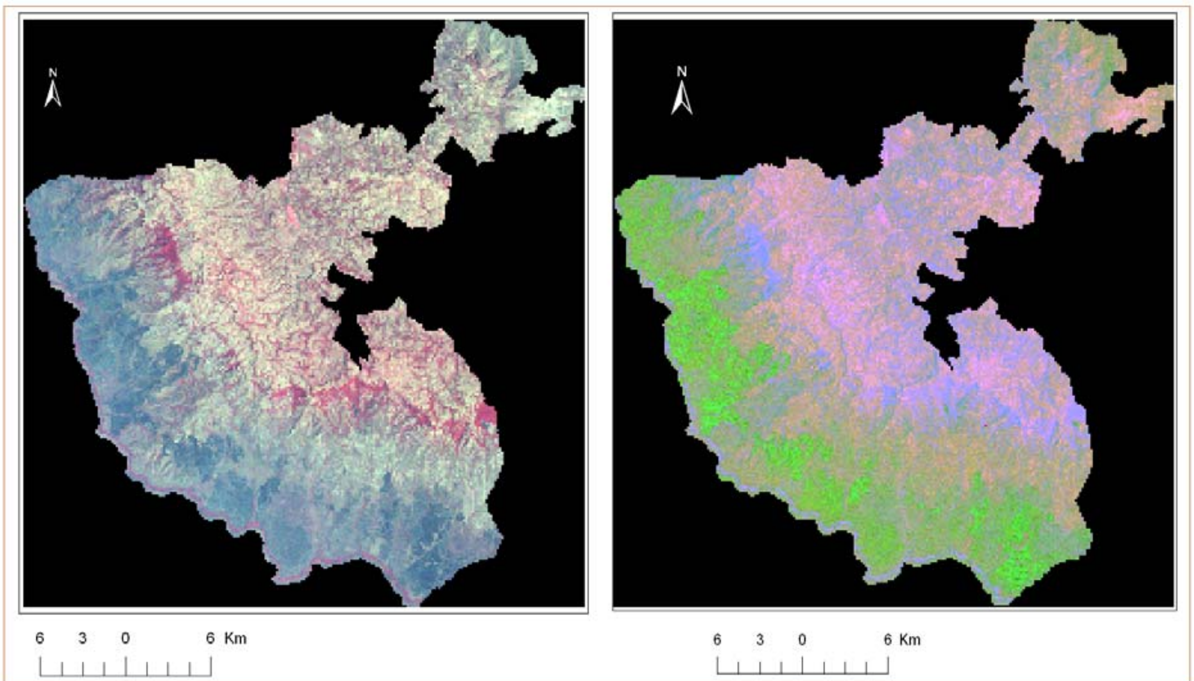

Figure 13: TCC of original (left) and FCC of IHS and Histogram Equalized image (right) of MSS

Vegetation index is the other enhancement technique used to analyze and aid visual and spectral interpretability of an image data. NDVI is one and a widely used image transformation to measure the presence and state of vegetation and to distinguish vegetated areas from others. It is computed from the spectral radiance in red(R) and near-infrared (NIR) bands (Eq. 1). The value ranges from -1 to 1, and the highest the value, the proportion of green vegetation in a pixel would be the highest and the lowest negative values are characteristics of either water or bare land ((Lillesand, *et al*, 2004 and Dagnachew Legesse, 2005) . A common range for green vegetation falls between ≈0.2 to 0.8 (ITT, 2006).

$$NDVI = NIR - R/NIR + R \text{ ……………………………………. } (1)$$

Over the study area, the different period images have different NDVI values. The MSS image has NDVI values that range from about - 0.5 to 0.6, the TM has values between -0.81 – 0.65 and that of ETM$^+$ falls between -0.8 and 0.4. These values indicate the state of green vegetation in that the higher the value the higher the amount of healthy green vegetation over an area.

4.1.1.2 Image Classification and Accuracy Assessment

I. Image Classification

The three time period images of the study area were first classified through computer automated unsupervised method in ERDAS IMAGINE 9.1 classifier. The output classes, though not exactly related to the direct meaningful characteristics of the scene, were assigned with names. It was this unsupervised classified image, that has been analyzed during the preliminary field visit and aid the subsequent supervised classification.

More over, during preliminary field visit, representative points in the study area, which were believed to represent the existing various land use/land cover category, were recorded using GPS (GARMIN72).

The combination of the visually interpretable data, field (GPS) data, pattern of spectral profile and the unsupervised classification, made supervised image classification possible. Accordingly, 7(seven) major land use/land covers classes namely: farm land, dense forest, degraded forest, open woodland, grassland; wetland and bare land were identified from the images (Fig. 14). The land use/land cover category of the area has been discussed here under:

1. **Farm Land:** This category involves both intensively and moderately cultivated agricultural lands. It appears with lighter to reddish pink color in FCC involving bands 2 and 3 on MSS; bands 7, 4 and 2 on TM and ETM$^+$. The built up areas were also categorized along with this class as it is difficult to separate them from landsat imageries. The central, eastern and northern plateaus and gentler slopes on MSS images were characterized by this category. On the TM and ETM$^+$ images, the area has been extended to south and covered some patches of rugged terrain with mid altitude and lowland parts of the study area. During the field visit, it has been realized that, the category is an area of both crop cultivation and cattle rising (plate 4).

Plate 4: Moderately cultivated sample area at Bedasa Didessa PA *(Photo by Muleta, April 2009)*

2. **Dense Forest Land:** This land cover type is characterized by closed canopy vegetation and the reverian forests. It is well identified in separate bands of 2 and 4 of MSS and bands 3 and 7 of ETM+ with dark to dark gray tone. With respect to color composites, they have bright red and bright green colors in TCC and FCC (7, 4 and 2 bands), respectively. This is related to their spectral characteristics as they reflect the green light of visible and higher NIR energy (Leica Geosystems, 2005). The vegetation index (NDVI) values also show this category clearly in that the highest NDVI values were characteristics of dense forests. On the MSS, this cover type is found in most PAs with irregular patches. They are common along ridges, escarpments and river courses. On the TM, it is observable at limited geographical areas (small patches on the escarpments of northern Hera, central Jamo Giros and between south central Asndabo and north eastern tip of Meta PAs) of the Woreda.
3. **Degraded Forest Land:** This class corresponds to plants which have under gone modifications from human's action. It is identified as lighter red and dark green in TCC and FCC (7, 4 and 2 bands) of the Landsat imageries, respectively. The category has NDVI values less than but follows the densely forested land. It occurs at the outer periphery of the dense forest, near farm land and around settlements. On the 1973 image, it is represented around the town of Arjo and in almost all PAs (except at the valley floor of Didessa and Wama Kura PAs) in small patches. How ever, on the image of the year 2001, such patches were concentrated around the remaining forest in the eastern side of Hine, western side of Hera, east central Tibe Chafe, south central Jamo Giros, eastern tip of Tibe

Kusaye and between south eastern and north eastern tips of Asndabo and Meta PAs as small patches.

4. **Grasslands:** In this study, areas in which grass is the primary natural vegetation or where an area is dominated by grasses, is categorized under this class. It covers mainly some patches of Didessa valley and the north eastern tip of the swampy areas. Such cover type flourished in relation to the availability of moist soils at the low lands. It appears in light tone in black and white and red pinkish in color composites on the Landsat image data.
5. **Open Woodland:** These are areas where sparse trees are dominant and associated with sparse grass. The category is characterized by natural or semi-natural sparse woody vegetation with opened canopy. It includes areas of pasture lands or grazing areas (plate 5). It dominates almost all the flat to undulating Didessa valley. The category can be identified at bands 2 and 4 with light tone and in pinkish red color of the Landsat imageries.

Plate 5: Open wood land regeneration from fire in Didessa valley *(Photo by Muleta, February 2009)*

6. **Wetland:** This category includes areas of seasonally flooded lowlands dominated by grasses and emergent vegetations which have roots in soil covered or saturated with water and its leaves held above water. Such class has an irregular darker to grey tone at band 4 of MSS and band 7 of TM and ETM^+.
7. **Bare land:** This includes areas covered by soil, sand or rocks. The class can be identified on bands 1, 2 and 4 on MSS. It appears yellowish red to human eye in TCC of the Landsat Imageries.

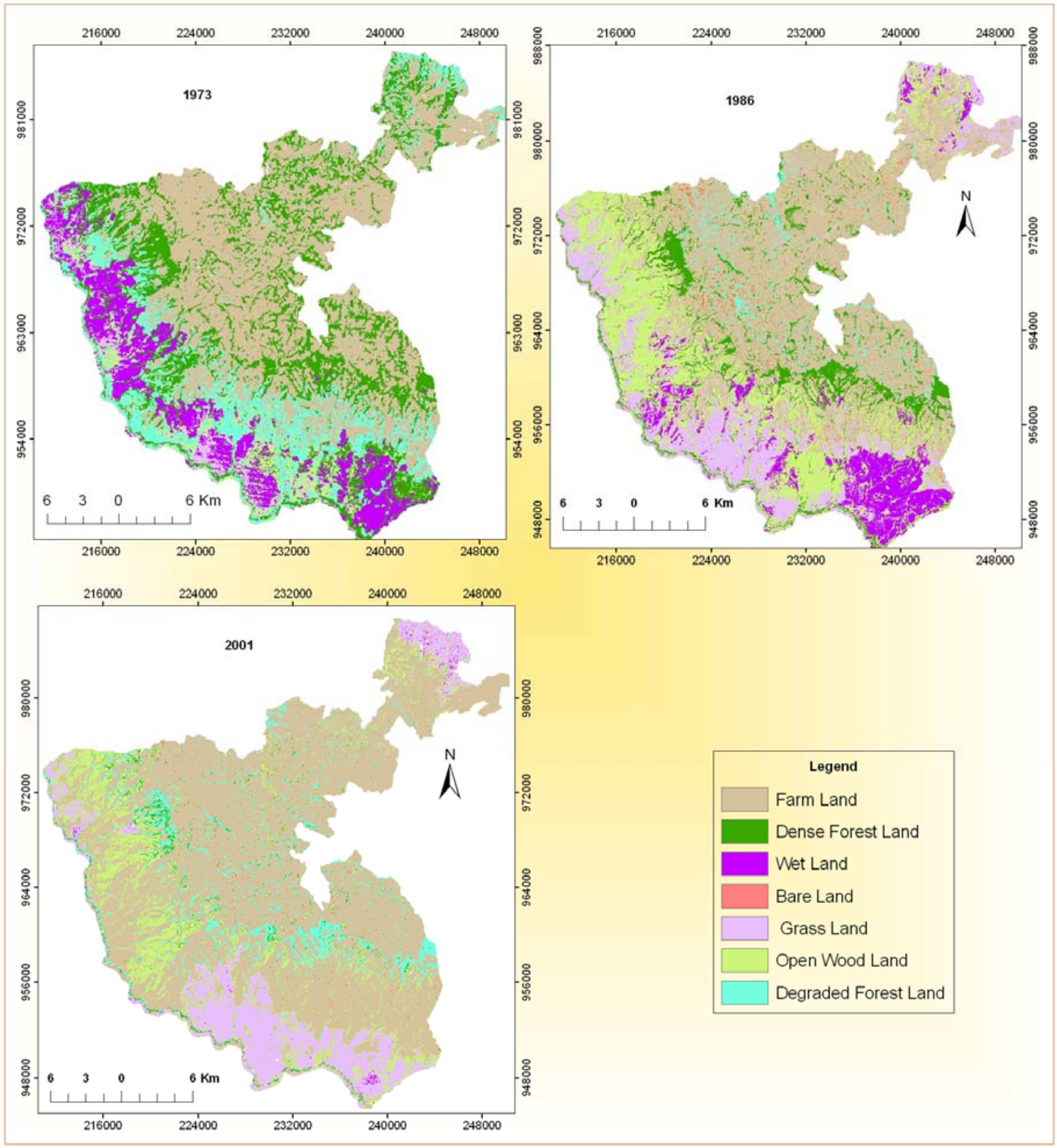

Figure 14: Land use/land cover map of Jima Arjo at different years

II. Accuracy Assessment

After classification of satellite images, the accuracy of the classification derived from remote sensing sources is required to be assessed. One of such a method is the use of a confusion matrix which is produced from the random sample of individual pixels/clusters compared to known cover conditions over the same pixel areas. It can give us a percentage of correctness of the classification result. The average for all classes in the image can give us the over all accuracy

(Dagnachew Legesse, 2005). Accordingly, the classified image data of 2001 has overall accuracy of 85% with kappa statistics of 0.72.

4.1.2 Land Use/Land Cover Change Susceptibility Factors Data Generation

Land use/land cover change is determined by different factors. The more the area and cover suitable for use, the more susceptible it is for change and degradation. Fite Getaneh (2008) considered altitude, accessibility, settlement (towns), slope and rivers as factors for land resource mainly forest resource mapping. Mannion (2002) described transport networks and Wright (1993) described accessibility to the land resources as the major driving forces of land cover change. In addition, soil is the other factor that determines land susceptibility to different land uses particularly for agricultural purposes (Mesfin, 1998). Yet, Troeh, et al., (1980), considered land cover type for land susceptibility to agriculture. Accordingly, for change and future trend analysis of the study area, accessibility, proximity to towns, proximity to rivers, slope, soil, agroclimate and the land cover data were considered as major factors since they are the determinants of land susceptibility for human uses. Although, geology is one of the factors that affect land use/cover, most part of the study area is covered by the rocks of Alghe group (Fig. 10). More over, the effects of geology have been assumed to be realized from the soil and slope of the area, its layer is not generated for land use/land cover change susceptibility.

These factors were generated, reclassified and analyzed in the ArcGIS 9.2 environment.

I. **Accessibility:** Roads, apart from the impact they have during their construction on land use/land cover, they provide a way for humans to access, use and change the land resources at any point (plate 6). Three classes of roads (the gravel all weather road that serve as a main road, dry weather roads and foot paths) were recognized and digitized from a topo map with scale 1:50,000. Based on the service intensity they provide to the society, maximum value has been assigned to the main all weather roads. The weather based roads provide service for vehicles based on weather conditions but used intensively for foot paths and hence assigned with the second high value. Foot paths were assigned with the least value since they provide service for only foot walk.

Plate 6: Wood logs for fuel and constructional purpose along road sides of Didessa Valley (left) and Tibe Chafe PA (right) to be transported*(Photo by Muleta, April 2009)*

II. Proximity to settlement (Town): The history of land use/land cover dynamics correlates to a greater extent with settlement patterns. With the expanding settlement, land resource use began to be complicated in response to the increasing demand and inevitably leads to fierce competitions and claims on the limited resources. Hence, areas nearer in proximity to the existing high population concentration centers are prone to land use/land cover change than other areas. During the field visit, it has been observed that forest resources as fuel wood, charcoal, timber and other constructional woods are carried to Arjo town continuously by human's, animal's back and cars (plate 7). There fore, proximity to towns digitized from the topo maps has been generated, reclassified and analyzed.

Plate 7: Wood and wood product market at Arjo town **(***Photo by Muleta, April 2009***)**

III. Slope: In agricultural based society with diversified land form, slope plays a great role. Slope is used as a significant factor to classify land systems. Accordingly, the slope of the study area has been categorized in to 7 classes. The slope up to 2^0 has been considered as flatter slopes and hence they are the most susceptible slope category. Slopes with 2 – 5^0 range was considered as gentle and holds the second suitable category. Those that range from 5^0 – 10^0 have been categorized as gentle to moderate sloppy; 10^0 - 16^0, 16 - 25^0, 25^0 - 35^0 and greater than 35^0 which is the extremely steep were the categories made based on their suitability level. Based on this fact, slope category of the area has been extracted from SRTM data followed by reclassification and assignment of values, ranks and weights using GIS plateforms (ArcGIS 9.2 and IDRISI 15 Andes).

IV. Soil: In agriculture base regions, land suitability largely depends on the soil character of an area. Soil's capacity and fertility to produce crop yield is determined by the quality of agricultural soil. Although, each land use has specific soil requirements, there are many soil properties which are important for most activities and crop productions. Accordingly, for agricultural yield production deep, loamy textured, good moisture retention capacity and adequate organic matter content are among the qualities of soils (Troeh, et al., 1980, Mesfin, 1998). From the digital soil data obtained from the MoA and RDE, Dystric Nitisols, Pellic Vertisols, Dystric Gleysols and Orthic Acrisol soil types were recognized in the study area. These soil types were assigned with suitability values for further processing. Dystric Nitisols are productive soils and have a potential under rain fed agriculture; Pellic Vertisols are highly productive but have low permeability; Dystric Gleysols have also good inherent fertility but require draining and protection from flooding as they occur on the alluvial plains; and orthic acrisols are shallow soils as they occur on steep side slopes (Mesfin, 1998). Accordingly, Dystric Nitosols have been assigned with higher values followed by Pellic Vertisols, Dystric Gleysols and that of Orthic Acrisols, respectively.

V. Agroclimate: As the area under investigation is predominantly an agricultural area, climate is also an important factor to be considered in determining land use/land cover. Three agroclimatic zones (Wet Kolla or tropical, Wet Weyina Dega or subtropical and Wet Dega or temperate highland) were recognized in the area (Fig.3). The highland climate is favorable and provided an excellent human habitat and hence already possessed by uniform land use where the land is almost intensively cultivated and densely settled than the other two zones. During the field work, interviews with peasant settlers and questionnaires for agricultural and rural development officers in the Woreda, it has been realized that young people, driven by land scarcity over the highland, moved and have been still moving in search of farm land to the unused peripherals of the subtropical and tropical zones of the area. More over, these zones were sought by the government as a site for resettlement program and investment agribusiness. Based on these evidences, factor values were assigned for land use/cover change analysis; more change factors for the subtropical followed by the tropical agroclimatic zones.

VI. **Proximity to Rivers:** Most of the river gorges of the area are characterized by dissected irregular steep sided slopes. They are less suitable to work on. Yet, areas nearer to rivers were found infested with cattle and human diseases such as malaria. Some wild animals that may destroy farm crops (like apes) and dangerous reptiles (like snakes and crocodiles) were also found in and around some rivers. Therefore, areas nearer to rivers are less likely to be encroached with in the current situation and hence assigned with low change factor values.

V. **Land Cover Type:** Land use systems currently contributing more to land cover changes are also determined by the type of land cover over a given area. Some cover types are favored to others for a given activity. To determine susceptible areas to change over the study area, the land use/cover data obtained from the 2001 image data has been used and scale values were assigned for each land cover type. As there is hardly any activity that does not use forest and forest products over the study area, they are considered as the first victim of change. Thus, dense forest covers were assigned with maximum value followed by the degraded forest and open wood lands. After forests, grass lands are among the biomes most heavily used and therefore assigned with the next scale values. Wet lands and bare lands irrespective of their order were assigned with the next lower and least values respectively. As farm lands are already the result of the conversion of the existing land cover types, they were assumed as they are less prone to change unless intensifications and reestablishment of vegetation will be employed. Thus they were assigned with the 2nd lowest value.

These derived data have their own values and thus the original values of the input datasets are required to be replaced by new values in order to set them to a common scale for further analysis. Accordingly, reclassification of each independent factor has been made by assigning change factor or susceptibility values ranging from 1 – 7 (since the maximum class category is the land use/cover class with 7). Pair wise comparison was employed to the datasets in the IDRISI 15 Andes to obtain the weight of each factor in identifying more vulnerable areas. The required criteria are stated in table 4 and the factor layers were indicated under (Fig.15).

Table 4: Factors of land use/cover change scale values and their associated weight

Factors	Assigned Scale Values							Weight
	7	6	5	4	3	2	1	
Land Cover Type	Dense Forest	Degraded Forest	Open Wood	Grass Land	Wet Land	Farm Land	Bare Land	0.1733
Soil Type	Dystric Nitisols	Pellic Vertisols	Dystric Gleysols	Orthic Acrisol	--	--	--	0.0551
Agro-Climate Type	Wet W/ Dega	Wet Kolla	Wet Dega	--	--	--	--	0.0559
Slope Range (Degree)	<2	2-5	5-10	10-16	16-25	25-35	>35	0.1947
Distance to All Weather Road(Km)	<2	2 - 5	5 - 8	8 - 12	12 - 16	16 - 22	>22	0.1460
Distance to Dry Weather Road(Km)	<1	1 - 3	3 - 6	6 - 10	10 - 15	15 - 22	>22	0.1127
Distance to Foot Path(Km)	<1	1 - 3	3 - 5	5 - 7	7 - 10	10 - 15	>15	0.0856
Distance to Town (Km)	<3	3 - 6	6 - 10	10 - 15	15 - 21	21 - 27	>27	0.0854
Distance to Rivers (Km)	>9	6 - 9	4 – 6	2 – 4	1 – 2	0.5 – 1	<0.5	0.0912

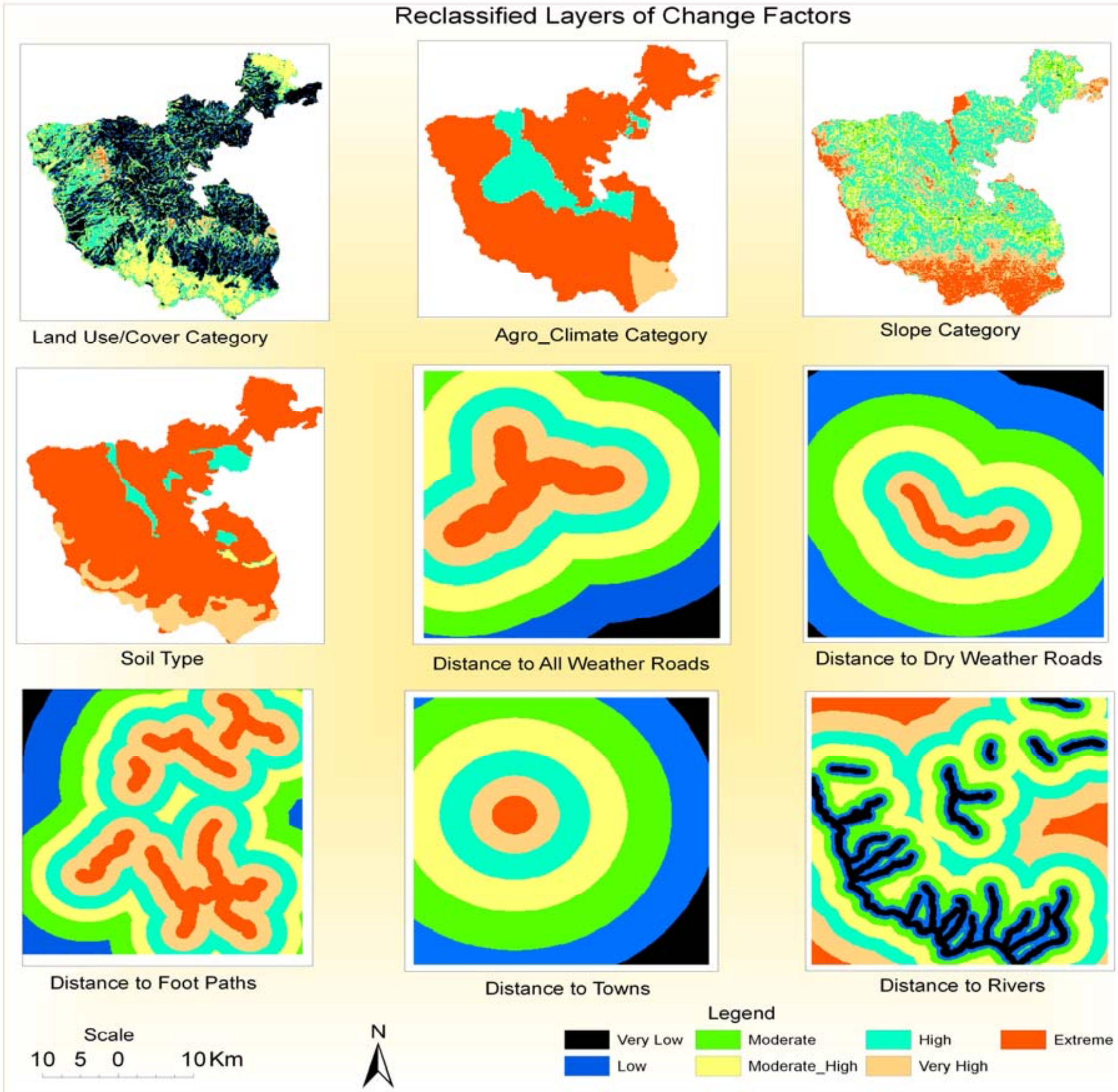

Figure 15: Map of reclassified factor layers of susceptibility to change

4.2 Soil Erosion Analysis using USLE Model

Soil erosion, in washing out the cultivated earth layer with its nutrient and organic matter content down hill or further in to rivers, is considered as a main agent of soil degradation. In the study area, the state and rate of soil erosion has been assessed using USLE model. As the model estimates soil loss from interlinked parameters, generated from climate, soil, terrain, land cover and management practices, GIS has been employed to generate and integrate the parameters using the principles of the model.

4.2.1 Derivation of USLE Model Parameters

The USLE model is an attempt to express the complexity of erosion phenomenon by describing it through six factors: rainfall Erosivity, soil erodability, slope gradient, slope length, and cover management and erosion management practices (Morgan, 1996). By quantification and multiplication of these six factors soil loss occurring on a specific plot of land can be modeled. As the model initially has made for the USA, the individual factors were designed for the natural conditions recognized there. Therefore, its application in Ethiopian conditions necessitates the modification of some of the factors. As cited in Krauer, (1988), Hurni, (1985), adapted the USLE model to the Ethiopian conditions by modifying some of the factors to the real situation of the country. In this study, these modified factors were generated as explained here under.

4.2.1.1 Rainfall Erosivity (R) Factor: This refers to the aggressiveness of the climate and is a measure of the potential of the eroding agent. It is the property of rainfall related to the detaching power of the rain drops to cause erosion in a given circumstance (Lal, 1981). It is commonly expressed in terms of the kinetic energy of the rain and is a measure of the combined effect of rainfall and the associated runoff. The detaching power of rain drops are positively correlated with rainfall intensity and hence rain fall erosivity tends to be greatest in areas where there is a marked seasonal concentration of rainfall (Ellis and Mellor, 1995). Thus, rainfall kinetic energy and intensity data are required to estimate rainfall erosivity.

As stated by Morgan (1996), Wischeier and Smith (1958) and later on Hudson (1965) and others obtained an equation to determine the kinetic energy and rainfall intensity for different regions. For Ethiopian case, to calculate rainfall erosivity, kinetic energy and intensity of rainfall are not available in most cases. There fore, Hurni (1985) as cited in Kruer (1988) derived an equation from a spatial regression analysis based on the easily available mean annual rainfall (P). The regression equation is given as:

$$R = -8.12 + (0.562 * P) \qquad (2)$$

Where: R is rainfall erosivity

P is the mean annual precipitation (mm/yr)

For the study area, the mean annual rainfall data of 10 stations (Arjo, Getema, Bedelle, Arb Gebeya, Nekemte, Atnago, Kone, Gunjo Mariam, Dedessa and Biloboshe) over 19 years (1988 – 2006) was considered to calculate the R-factor (Table 5). It is quite worthy to recognize the annual rainfall distribution over the area (Fig. 4). Summer months are periods of maximum rainfall and hence the amount of rainfall in these months is quite significant in understanding the phenomena of erosivity.

Table 5: R - factor values of the rainfall stations

Station Name	Location		Altitude (m)	Mean Rain fall (P) from 1988 – 2006 years (mm)	R-Factor
	Latitude	Longitude			
Arjo	$8^0$45'N	$36^0$30'E	2565	1855.1	1034.5
Getema	$8^0$54'N	$36^0$28'E	2110	1392.2	774.3
Bedelle	$8^0$27'N	$36^0$20'E	2030	1861	1037.8
Arb Gebaya	$9^0$03'N	$36^0$45'E	---	1528.9	851.12
Nekemte	$9^0$05'N	$36^0$28'E	2080	2099.2	1171.63
Atnago	$8^0$19'N	$36^0$56'E	1850	1681.1	936.66
Kone	$8^0$41'N	$36^0$47'E	2000	1713.1	954.64
Gunjo Mariam	$8^0$56'N	$36^0$50'E	---	1422.6	791.4
Dedessa	$8^0$06'N	$36^0$23'E	---	1487.4	827.80
Biloboshe	$8^0$54'N	$36^0$59'E	1630	1468.5	817.20

(Source: NMA, 2009)

The calculated R-factor for each station has been converted to raster surface using ArcGIS 9.2 Geostatistical IDW interpolation techniques (Fig. 16).

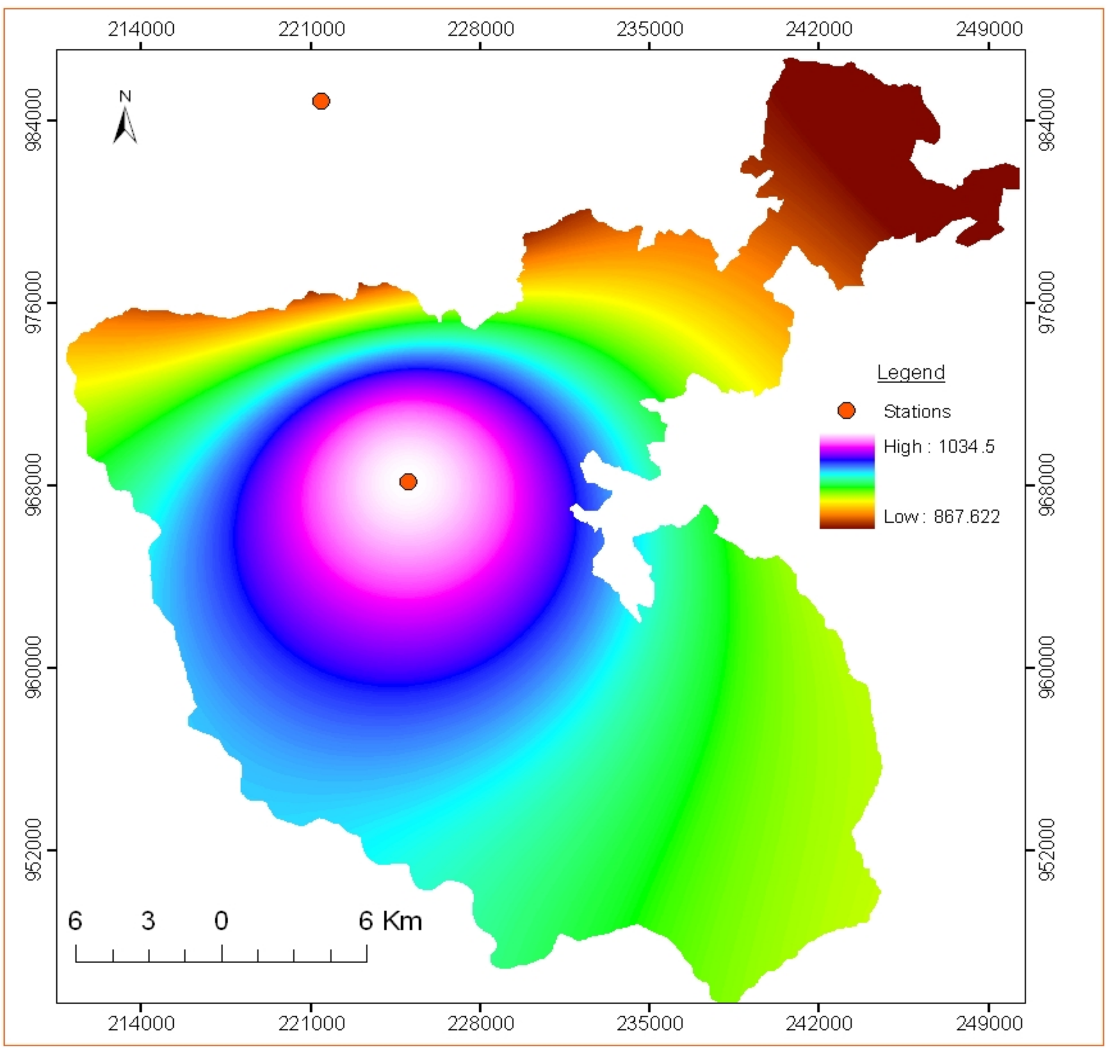

Figure 16: R-factor raster map of the study area

4.2.1.2 Soil Erodability (K) Factor: This is the property of soils which can quantitatively be evaluated as the vulnerability of the soil to erosion in a given circumstance. Erodability of a soil is a measure of its resistance to detachment and transport by rainfall and runoff. It depends mainly on the texture of the soil. The aggregate stability, shear strength, infiltration capacity and organic and chemical content of soils are also the contributory factors (Ellis and Mellor, 1995). The K-factor is estimated based on soil erodability index, which is the mean annual soil loss per unit area of rain for standard condition of bare soil, recently tiled up without any conservation on slope gradient of 9^0 and slope length of 12m (Tsegaye Berkineh, 2007).

Hurni (1985) cited in Krauer (1988) estimated the K-factor values for soil types from the experiment conducted on some six research centers in Ethiopia. For undetermined soil types, soil colors were proved to be used to estimate the values. This is because soil colors have long been the best known characteristics and easily identifiable part of the soil properties since they show mainly the kind, amount and distribution of organic matter and mineral substance of the soil (Geremew Bayeta et al., 1998). Based on this, the K-factor values for the four soil types of the study area (see under 4.1.2.1), have been assigned (Table 6). Following the assignment procedure, the K-factor map of the study area has been converted to raster using the K-values field with a grid cell size of 30m resolution (Fig. 17).

Table 6: Soil type and K - factor values

Soil Type	K-Values
Dystric Nitisols	0.25
Pellic Vertisols	0.22
Dystric Gleysols	0.31
Orthic Acrisols	0.22

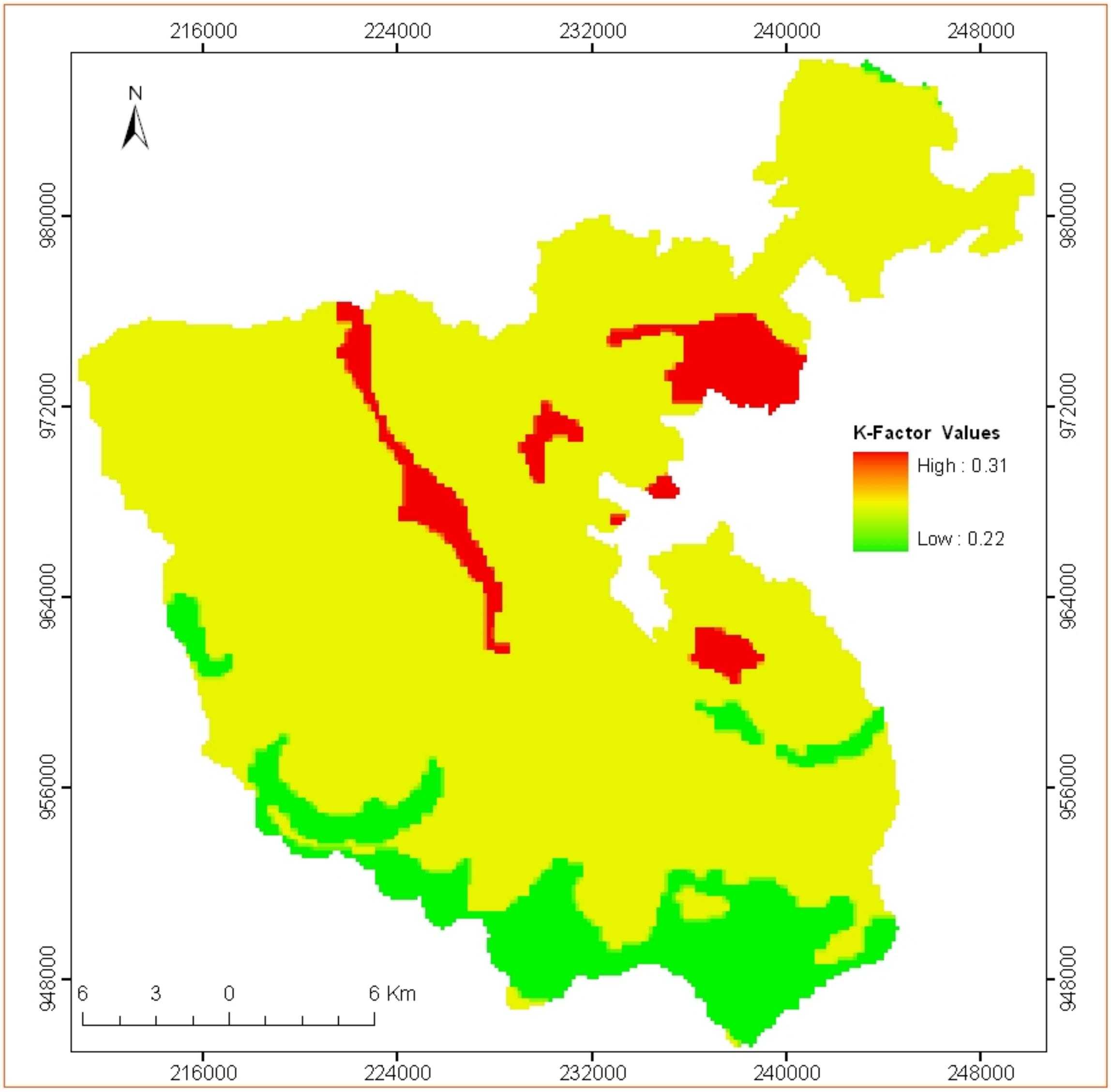

Figure 17: K-factor raster map of the study area

4.2.1.3 Topographic or Slope Length and Slope Gradient Factors: A field's length and slope interact in the amount of erosion that occurs. Thus, the longer and the steeper the slope, the more erosion would occur (Clark II et al., 1985 and Morgan, 1996).

I. Slope length (L) Factor: is the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or the runoff water enters a well defined channel. Soil loss generally increases substantially as slope length increases because greater accumulation of runoff on the longer slopes increases detachment and transport capacity. Slope length indicates the ruggedness of an area and the shorter the slope length the more rugged it is. Helden (1987), described slope length factor using the following formula.

$$L = 0.799 + 0.0101 * flowacc \quad \ldots\ldots (3)$$

Where: L is slope Length factor

Flow Accumulation is the number of cells contributing to flow in to a given cell

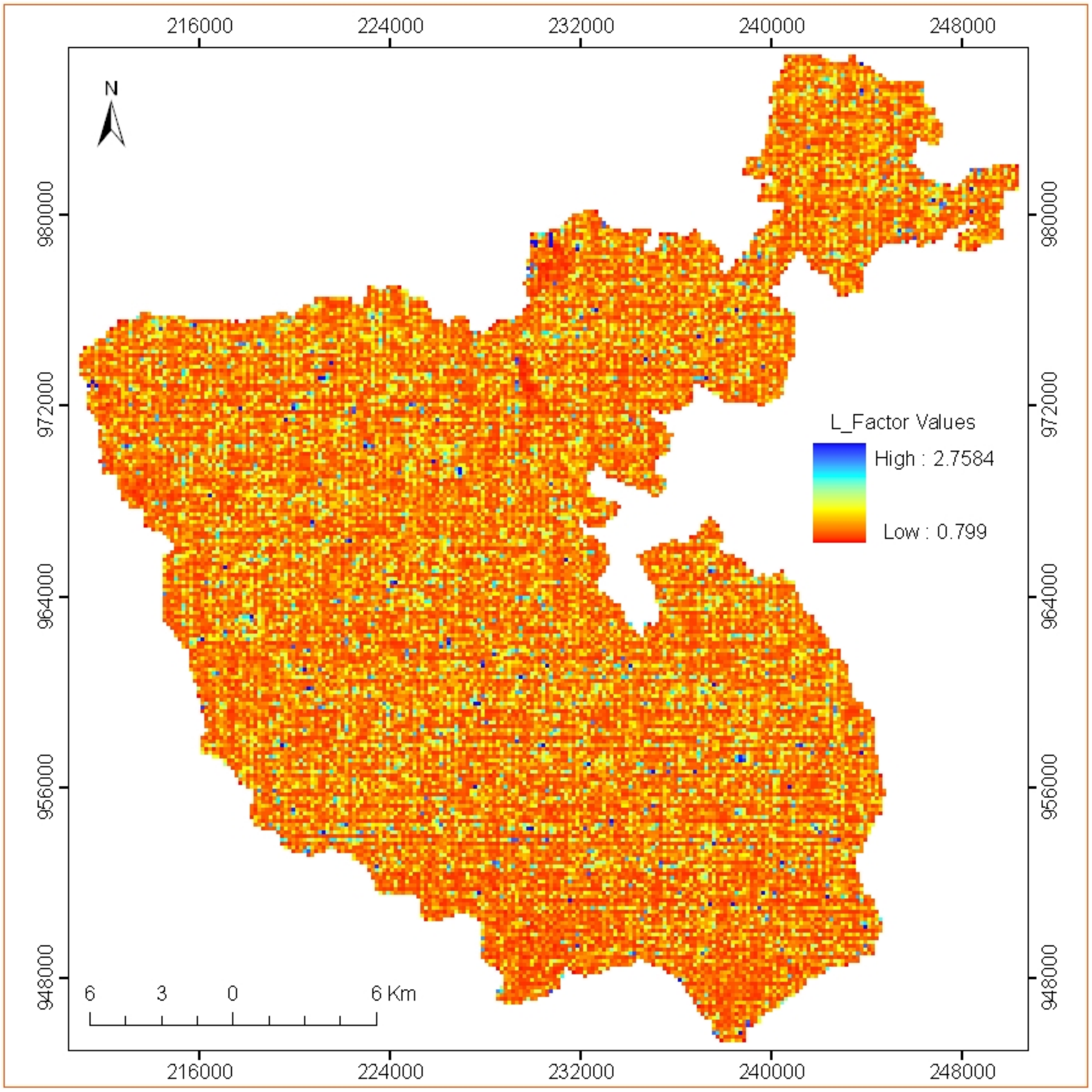

Figure 18: L-factor raster map of Jima Arjo

The slope of the study area has been extracted from SRTM data and then the flow accumulation has been derived using ArcGIS spatial analyst tools. As can be seen from the output map (Fig. 18), areas with higher L-factor values are more rugged and hence are more vulnerable to erosion.

II. **Slope Steepness (S) Factor**: This refers to the slope gradient or shape of the slope. The velocity of water movement and its ability to detach and carry soil particles increase exponentially with increase in slope gradient and hence Soil loss increases rapidly as slopes steepen. Slope can be derived from SRTM - DEM using ArcGIS

Spatial Analyst Tools by considering the concept of change in value between neighbor raster cells. Maximum slope value corresponds to the steepest gradient and the lower the value the flatter the area is.

The S-Factor for the study at hand has been derived from SRTM-DEM data by applying the equation obtained from Helden (1987) (Eq. 4) in the raster calculator function (Fig. 19).

$$S = 0.344 + 0.0798 * \text{Slope gradient} \quad (4)$$

Where: S is the slope gradient factor

Slope gradient is the incline or steepness of a surface in percent

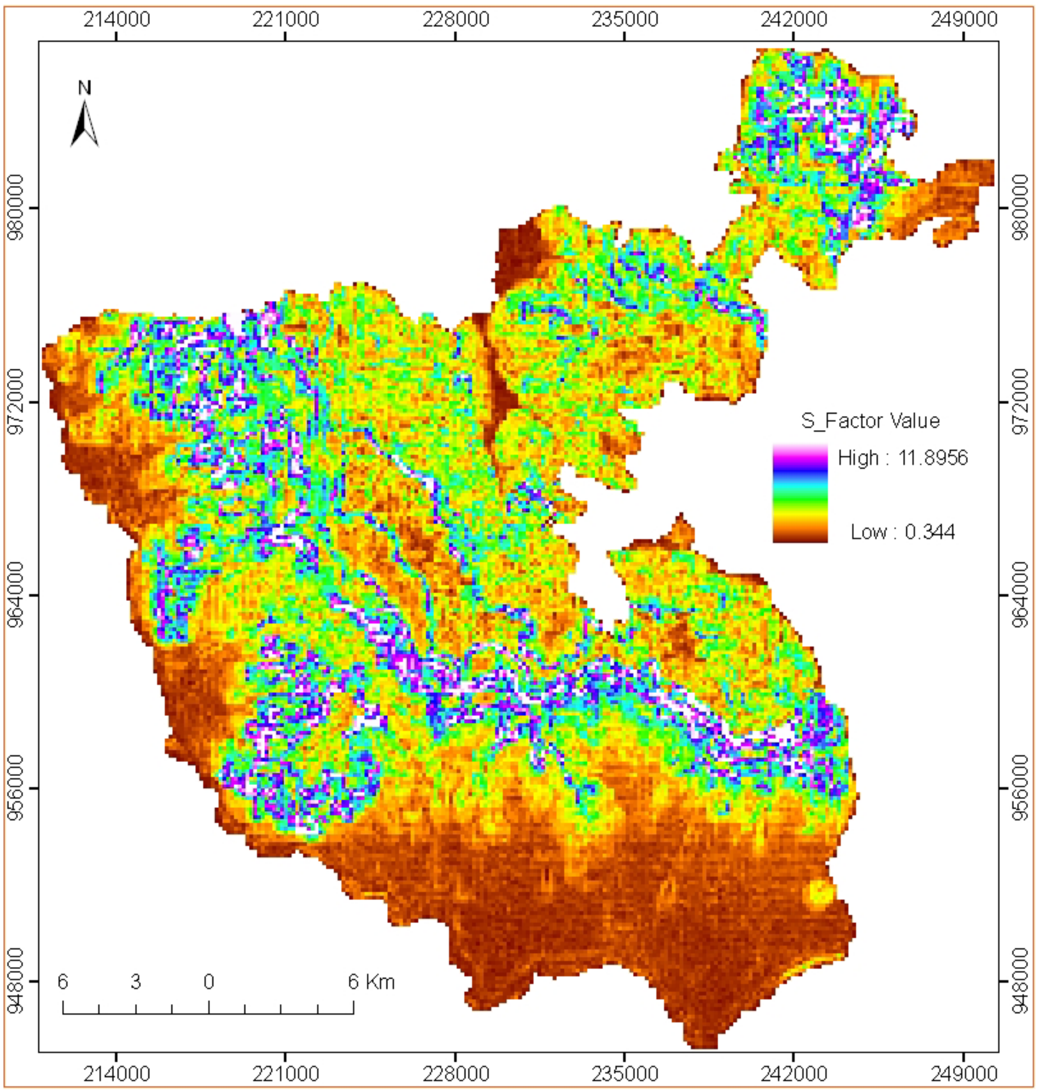

Figure 19: S - factor map of Jima Arjo

4.2.1.4 Cover Management (C) Factor: This is defined as the ratio of soil loss from a given land use/land cover type, specifically cropped land, under specified conditions to the corresponding loss from clean tilled and/or bare soil (Samuel Chemeda,2007). It is often associated with the land use/land cover type and is perhaps the most significant factor influencing the amount of soil erosion.

It is evident that, cover management affects the level of erosion in different ways. In a complete canopy of crop leafs covering the soil, falling rain does not hit the soil surface with full velocity and consequently has less energy to detach the soil particles. Moreover, crop residuals on the soil surface or the closely growing of vegetations not only interferes with raindrops striking the surface but also slows the rate at which water flows over the surface, reducing its soil carrying capacity and increases the amount of infiltration.

As the original parameters of USLE model were restricted to USA east of Rocky Mountains, several attempts have been made to apply the equation more widely over varied countries. Therefore, based on the idea that different cover types respond to the amount of falling rain and runoff differently and thus yields different C-factor values, the factor values were assigned to different cover and practice types (Morgan, 1996). Hurni (1985) cited in Krauer (1988) estimated C-factor values for different cover types over Ethiopian highlands.

Over the study area, it has been realized from the questionnaires and interviews supported by field observation that different crops were found growing based on the agroclimtic zones. Except barley, which grows two times per year, only one crop was found harvested per field each year. Over the highland areas, barely, wheat, horse bean, lentils and teff are common crops. This zone is an intensively cultivated area. In mid altitude zones, maize, nigerseed, sorghum, millet, teff, oat and others were recognized. Most of these crops were found on moderately cultivated land use/land cover category.

Based on the estimated values by Hurni (1985), cited in (Krauer) and Morgan (1996), C-factor values were assigned to each of the land use/land cover classes (Table 7) recognized over the study area as extracted from the2001 year's ETM^+ image. In order to identify specific values for each land use/cover category, the image data classified into seven categories (under 4.1.1.2 image Classification) was reclassified further into eight categories by classifying the farmland in to intensively and moderately cultivated farm land (Fig. 20).

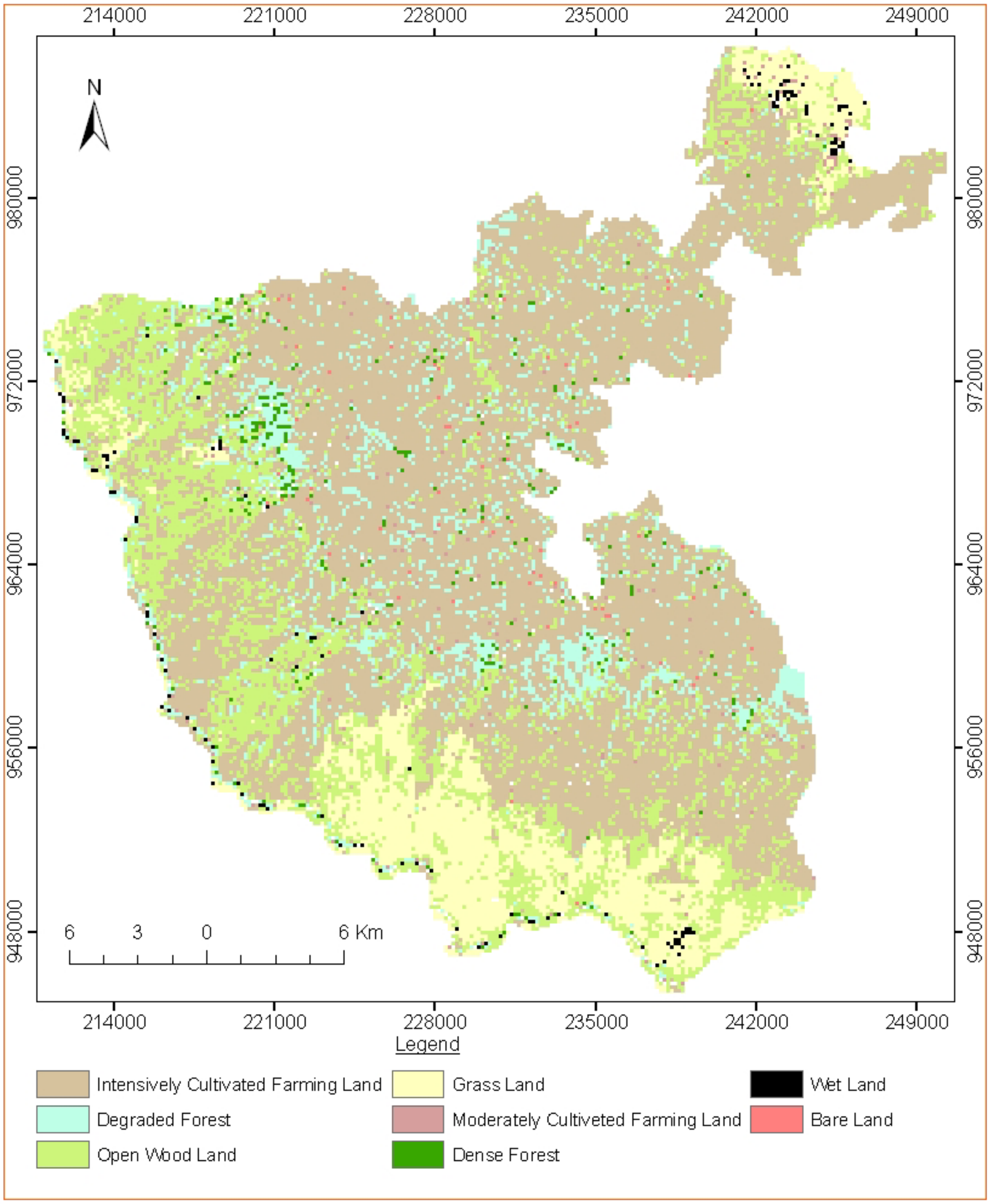

Figure 20: Land use/cover map of the year 2001 for C and P factors generation

Finally, raster - vector format conversion and vice-versa has been made to the land category using ENVI 4.5 software and the crop management factor (C-factor) values were assigned to each category (Table 7) and processed using ArcGIS 9.2 software Conditional Spatial Analyst Tools. Average values have been assigned for some cover types for which the exact value was not found and the result has been made displayed in a grid map of 30m cell size (Fig. 21).

Table 7: Estimated cover management (C) factor

Land Use/Land Cover Type	C-Factor Value
Intensively Cultivated Farm Land	0.15
Moderately Cultivated Farm Land	0.10
Dense Forest	0.001
Degraded Forest	0.05
Grass Land	0.01
Open Wood Land	0.05
Swampy Land	0.01
Bare Land	0.05

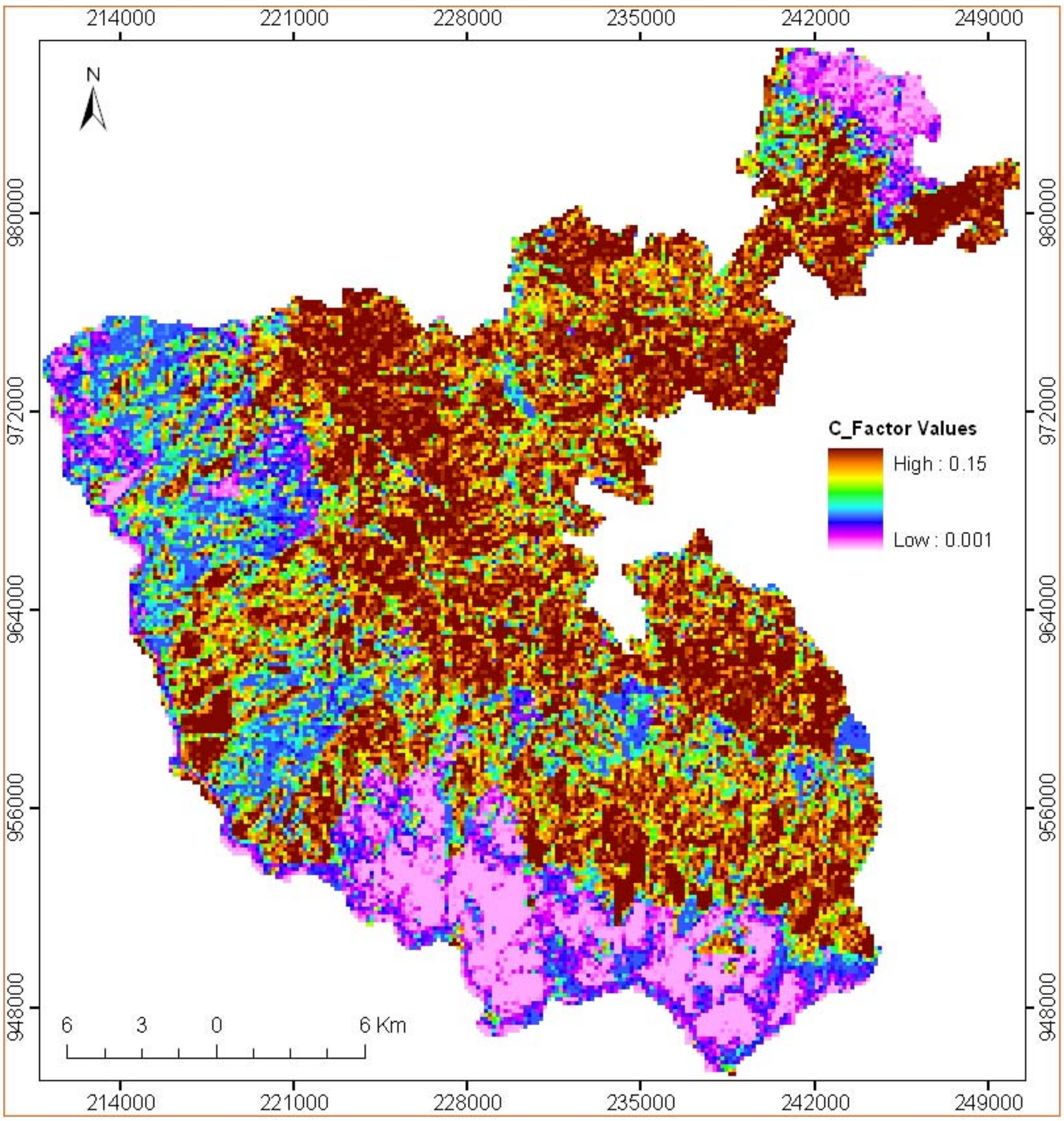

Figure 21: C - factor map of the study area

4.2.1.5 Support Practice (P) Factor: P refers to the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope culture. The factor takes into account the use of farming techniques as contour plowing, strip cropping or terracing that tend to lessen soil erosion. Such practices reduce the rate at which water flows over the soil surface and also increases the amount of infiltration that occurs (Clark II et al., 1985).

P-factor value estimations were made by different researchers at different locations. In any case, the values were obtained from tables of the ratio of soil loss where the practice is applied to the soil loss where it is not (Morgan, 1996). The P-factor values ranges from 0 – 1 and are required for agricultural land only. Unlike agricultural lands, other land uses, were found with no any control practice measures and hence P-values were assumed as one. Hurni (1985) cited in Krauer (1988) adapted and assigned the P-values to the cultivated highlands of Ethiopia. Based on this, different researches have been conducted in Ethiopia and estimated the soil loss. Samuel Chemeda (2007) used the adapted p-value and obtained a good soil loss estimation result.

Estimation of the P-factor values for the study area was carried out taking into account the local management practices found during the field survey. It was observed that, in almost all the highland and mid altitude areas, farmers plough their farmlands in different directions with traditional ox drawn subsoiler ploughs that penetrates into and scratches the soil many times before broadcasting the seed. Over these areas where intensive and moderate cultivation was taking place the prevention of erosion and runoff on crop fields across varied slopes has been recognized through construction of furrows, water ways, some graded bunds and contour ploughing. Considering these practices, the 8 class image data has been assigned with P- Factor values (Table 8) based on the estimation made by Hurni (1985), cited in Krauer, (1988). After the necessary raster-vector with 30m cell size conversions were made, the map has been displayed (Fig. 22).

Table 8: Land use/cover and the associated support practice (P) factor values

Land Use/Land Cover Type	P-Factor Value
Intensively Cultivated Farm Land	0.9
Moderately Cultivated Farm Land	0.9
Denser Forest Land	0.7
Degraded Forest	0.8
Grass Land	0.7
Open Wood Land	0.8
Swampy Land	0.7
Bare Land	1.00

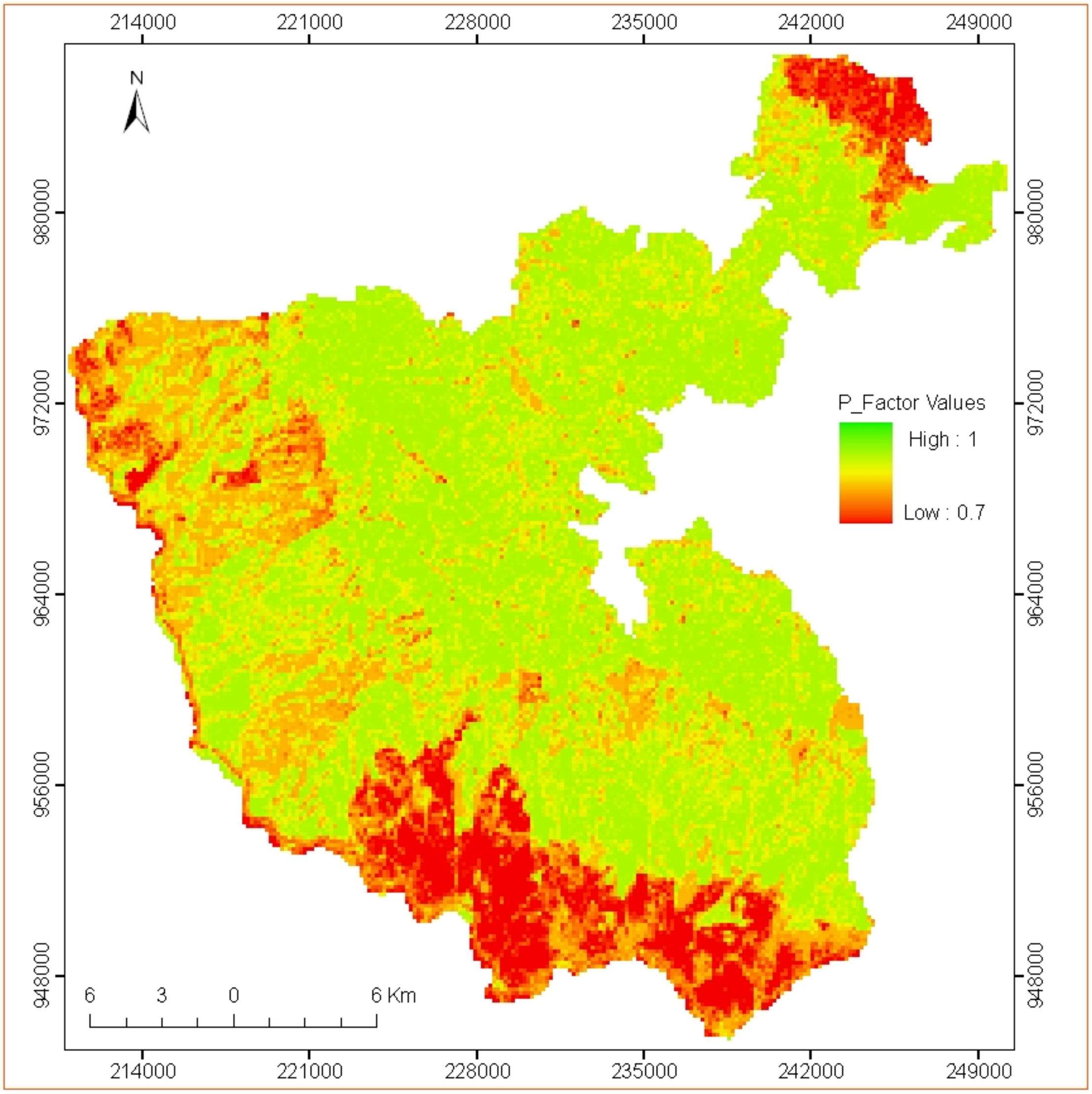

Figure 22: P - factor map of the study area

5 RESULTS AND DESCUSSIONS

5.1 Land Use/ Land Cover Change and Land Degradation Assessment

In the study area, the temporal and areal dynamics of various land use/land cover categories across 1973 – 2001 have been analyzed. Analyzing the change at different times, help in determining the causal factors, the level of the change and the respective management techniques. For this purpose, satellite images of 1973, 1986 and 2001 have been considered. The whole time range has been segmented into two; 1973 – 1986 and 1986 – 2001 and finally the overall change (1973 – 2001) has been assessed. The rate of change (difference in area from the final to the initial state of each land use/cover category over the specified time period or number of years in each period) across the study period has also been analyzed based on the statistical data derived from the images (Tables 9, 11 and 13).

In order to put a clear picture and understanding of the land use/land cove dynamics, change matrix has been generated on the basis of the classified image data (Tables 10, 12 and 14). These tables show the areal distribution of each land category that have undergone conversion and/transformation from one category to the other.

5.1.1 LU/LC Change between 1973 to 1986

Between 1973 and 1986 (Table 9), open wood land and dense forest land showed maximum changes; where the first one increased in 14,012.4ha with 1077.9ha/yr mean rate of change; but the later one decreased with 11,258.7ha (866.1ha/yr). Degraded forest and grassland also showed significant changes in that the earlier one has decreased with 8501.7ha (653.9ha/yr negative rate of change) but the later one has expanded with 7,659.1ha (rate of 589.2/yr). Wet land has also reduced with 2,719.4ha but bare land showed some degree of expansion. Agricultural land in this period showed very small expansion (155.1ha) and the rate of expansion over the period has been estimated as11.9ha/yr which is the lowest rate of change comparatively.

Table 9: Extent of land use/cover change in 1973 and 1986 years

LU/LC Category	1986		1973		Average Rate of Change (ha/yr)
	Area (ha)	%	Area (ha)	%	
Farm Land	33,841.10	43.8	33,686	43.62	11.9
Dense Forest	6,679.70	8.6	17,938.4	23.2	-866.1
Degraded Forest	2,249.30	2.9	10,751	13.64	-634.6
Grass Land	10,825.30	14.1	3,166.2	4.113	589.2
Open Wood Land	17,527.50	22.7	3,515.1	4.524	1077.9
Wet Land	5,733.50	7.4	8,452.9	10.9	-209.2
Bare Land	401.6	0.5	0.3	0.003	30.8
Total Area	77,258	100	77,258.00	100	-----

The data of the change detection matrix (Table 10) clearly indicates the trend of each land category in this period. Farm land which was the largest land category (over 43%) over the period has not shown significant change owing to loose and gain of an area. While it gained 69.55 Km^2 areas mostly from dense forest (48.94Km^2) and degraded forest (13.57Km^2), it lost 67.06Km^2 of area to other land category (mainly to open wood land and grassland). Insignificant portion of the farm land (0.28Km^2) has converted to dense forest due to some forest reestablishment and afforestation of a degraded farm land.

Table 10: Land use/cover change matrix of 1973 and 1986 years image data

Land Use/Cover Category		Initial State in km^2 (1973)							
		Farm Land	Dense Forest	Degraded Forest	Grass Land	Open Wood Land	Wet Land	Bare Land	Class Total
Final State (Km^2) in 1986	Farm Land	267.94	48.94	13.57	1.34	2.25	3.44	0.01	338.411
	Dense Forest	0.28	61.67	3.6	0.2	0.26	0.33	0	66.71
	Degraded Forest	6.56	5.25	10.11	0.04	0.05	0.03	0	22.28
	Grass Land	23.31	7.28	22.15	16.56	12.09	25.58	0	108.25
	Open Wood Land	30.05	38.54	44.94	10.4	14.83	35.3	0	174.92
	Wet Land	3.06	16.41	9.44	2.92	5.49	19.63	0	57.29
	Bare Land	3.8	0.06	0.13	0	0.01	0	0	4.02
	Class Total	336.86	179.38	104.99	31.66	35.15	84.53	0.01	---
	Class Changes	68.92	117.71	94.88	15.1	20.33	64.9	0	---
	Image Difference	1.6	-112.68	-82.49	76.5	139.77	-27.24	4.01	---

Note: The numbers in the row class total indicate the initial state whereas that of the column indicate the final state of a given land use/ land cover type in Km^2. The Diagonals indicate areas that remained unchanged.

Dense forest, in addition to its conversion to farm land, has been transformed into open wood land and thus has shown significant reduction (about 112.7Km^2). Yet, some of the dense forest lands at the initial period were abandoned and transformed to grass lands and degraded forests. Of the original 104.99km^2 area of degraded forest land, only 10.11km^2 area has been left unchanged during the final state. Apart from its transformation to farm lands, it has been converted to open wood land, grass land and partly to others. Although, the grass land category expanded over the period, some of it has been transformed and gave a rise to the revival of some woody land trees and others. The open wood land, owing to less contribution to transformation/conversion and the conversion of other land categories to it, increased in size more than the other categories. Much of the initial state of the wet land has also converted to open wood land and grass land and hence declined in size at the final period. Comparatively, the bare land though has least areal converge over the period, has increased in extent.

5.1.2 LU/LC Change between 1986 to 2001

This period clearly showed the massive land transformation and magnified the state of human intervention in an ecosystem. With more or less equal time interval with that of the previous study period, the amount of farm land has increased extremely (increased with 15,171.5 ha as compared to 155.1ha in the previous period) with 1011.4ha/yr average rate. Large patches of native vegetations have been removed, degraded and either converted or transformed in to farm land. Dense forest has shrunk to the level of inexistence being pushed by the expanding agricultural frontier and other forest product consumption. It constituted only 1,073.40ha in 2001 (1.4% of the woreda's total area) area. Degraded forest area has expanded over the period. The original grass lands, open wood lands and swampy lands were drastically diminished. Bare land showed expansion over the period (Table 11).

Table 11: Extent of land use/cover in 1986 and 2001 years

LU/LC Category	2001		1986		Rate of Change (hectare/yr)
	Area (Hectare)	%	Area (Hectare)	%	
Farm Land	49,012.60	63.4	33,841.10	43.8	1011.4
Dense Forest	1,073.40	1.4	6,679.70	8.6	-373.8
Degraded Forest	6234.4	8.1	2,249.30	2.9	265.7
Grass Land	9558.6	12.4	10,825.30	14.1	-84.4
Open Wood Land	10340.3	13.4	17,527.50	22.7	-479.2
Wet Land	268.8	0.3	5,733.50	7.4	-364.3
Bare Land	769.9	1	401.6	0.5	24.6
Total Area	77,258	100	77,258	100	

The table of matrix (Table 12) shows that the largest share of land category in the area, the farmland (with over 63% coverage), has expanded through out the period due to largely the conversion of the initial open wood land (74.49 Km^2) followed by grass land (47.97Km^2). During the period, even though farm land extended to dense forest land (with 32.27Km^2) not as such as compared with the expansion to that of the grass land. But the dense forest was radically diminished more than the grass land. It was degraded (16.19 Km^2), and also transformed to open wood land and grass land. This is really an indicator of other human interventions to forests since there was no any natural hazard recorded during the period. Some of the previously, wet lands, degraded forests and even the bare lands were also converted to farm lands at the final state of the period. Other than the farm land, it was the degraded forest land that showed relative increment in size during this period.

Table 12: Land use/cover change matrix of 1986 and 2001 years image data

Land Use/Land Cover Category		Initial State in Km^2(1986)							
		Farm Land	Dense Forest	Degraded Forest	Grass Land	Open Wood	Swampy Land	Bare Land	Class Total
Final State in Km^2 (2001)	Farm Land	301.21	32.27	7.94	47.97	74.49	23.57	3.49	490.06
	Dense Forest	0	6.08	0.16	0.92	2.62	0.3	0.02	10.73
	Degraded Forest	8.67	16.19	11.98	13.29	9.87	1.2	0.24	62.34
	Grass Land	16.22	2.18	0.29	29.5	27.64	19.3	0.03	95.53
	Open Wood Land	6.59	6.63	0.94	16.31	59.21	11.61	0.08	103.38
	Wet Land	0.28	0.12	0.02	0.75	0.82	0.57	0	2.69
	Bare Land	5.86	0.69	0.17	0.26	0.73	0.08	0.03	7.7
	Class Total	338.4	66.8	22.49	108.25	175.23	57.33	4.02	---
	Class Changes	37.16	60.72	10.51	81.44	116.02	56.75	3.99	---
	Image Difference	151.65	-56.06	39.85	-12.47	-71.85	-54.64	3.68	---

Note: The numbers in the row class total indicate the initial state whereas that of the column indicate the final state of a given land use/ land cover type in Km^2. The Diagonals indicate areas remained unchanged.

5.1.3 LU/LC Change between 1973 to 2001

Considering the over all study period, a remarkable increase in the areal extent of farm land has been evident; from 33,686 ha (43.62%) in 1973 to 49,012.60ha (63.4%) in 2001 with 15326.6ha variation across 28 years. While natural vegetations of grass land and wood land showed relative increment in coverage, the other categories of vegetations (dense forest, and the degraded forest were diminished at a higher rate, 602.3ha/yr and 152.3ha/yr). Wet land has reduced but that of bare land has increased in area (Table13).

Table 13: Statistical Summary of land use/land cover from 1973 - 2001

LU/LC Category	2001		1973		Rate of Change (ha/yr)
	Area (ha)	%	Area (ha)	%	
Farm Land	49,012.60	63.4	33,686	43.62	547.4
Dense Forest	1,073.40	1.4	17,938.4	23.2	-602.3
Degraded Forest	6234.4	8.1	10,499.1	13.64	-152.3
Grass Land	9558.6	12.4	3,166.2	4.113	341.2
Open Wood Land	10340.3	13.4	3,515.1	4.524	243.8
Wet Land	268.8	0.3	8,452.9	10.9	-292.3
Bare Land	769.9	1	0.3	0.003	27.5
Total Area	77,258	100	77,258.00	100	

The whole period clearly indicates how much dynamic the land use/land cover of the area is (Table14). Farm land, the greatest category at any of the periods, increased in area and left unchanged in greater amount (308.6Km^2). In areal order dense forest with 95.84 Km^2, degraded forest 51.31Km^2 area, open wood land with 13.7Km^2, grass land with 11.02Km^2 and the wet land with 9.58Km^2 were converted to farm land. It was only the bare land that was not converted to farm land. The dense forest has been transformed to farm land in greater amount and hence diminished greatly at the final state. The degraded forest has increasingly degraded further due to its conversion to open wood land (20.65 km^2) and grass land (7.99Km^2) in addition to its transformation to the farmland. Although, some of the areas were converted to the other class categories, open wood land and grass lands were increased relatively as a result of dense forest and degraded forest conversion to these categories.

Table 14: Summary of land use/cover change matrix of 1973 and 2001 years image data

Land Use/Land Cover Category		Initial State in Km^2 (1973)							
		Farm Land	Dense Forest	Degraded Forest	Grass Land	Open Wood	Wet Land	Bare Land	Class Total
Final State in Km^2 (2001)	Farm Land	308.6	95.84	51.31	11.02	13.7	9.58	0	490.12
	Dense Forest	0	7.78	1.6	0.32	0.49	0.42	0	10.81
	Degraded Forest	3.29	23.65	22.18	0.8	0.9	11.84	0	62.56
	Grass Land	10.04	18.64	7.99	14	13.03	31.79	0	95.49
	Open Wood Land	9.14	31.31	20.65	5.48	7.2	29.54	0	103.32
	Wet Land	0.06	0.61	0.71	0.17	0.18	0.81	0	2.63
	Bare Land	5.4	1.48	0.53	0.07	0.06	0.09	0	7.7
	Class Total	336.75	179.34	104.99	31.66	35.15	84.53	0	---
	Class Changes	29.75	171.56	82.81	17.66	27.95	83.92	0	---
	Image Difference	153.05	-168.53	-42.43	63.83	68.17	-81.89	7.7	---

Note: The numbers in the row class total indicate the initial state whereas that of the column indicate the final state of a given land use/ land cover type in Km^2. The Diagonals indicate areas remained unchanged.

Figure 23, below indicates the trend of each land category across 1973 to 2001.It clearly indicates the ultimate impact of extreme anthropogenic interventions in accelerating the removal of the original ecosystem over the area. This is evident in that as farm land has been increased dramatically, the dense forest has been declined extremely over the years. Degraded forest land declined at the beginning and showed some increment at the last. Grassland and open wood land both increased through 1973 – 1986 but begun to decline in 2001. While wet land declined continuously the bare land has shown increment over the periods.

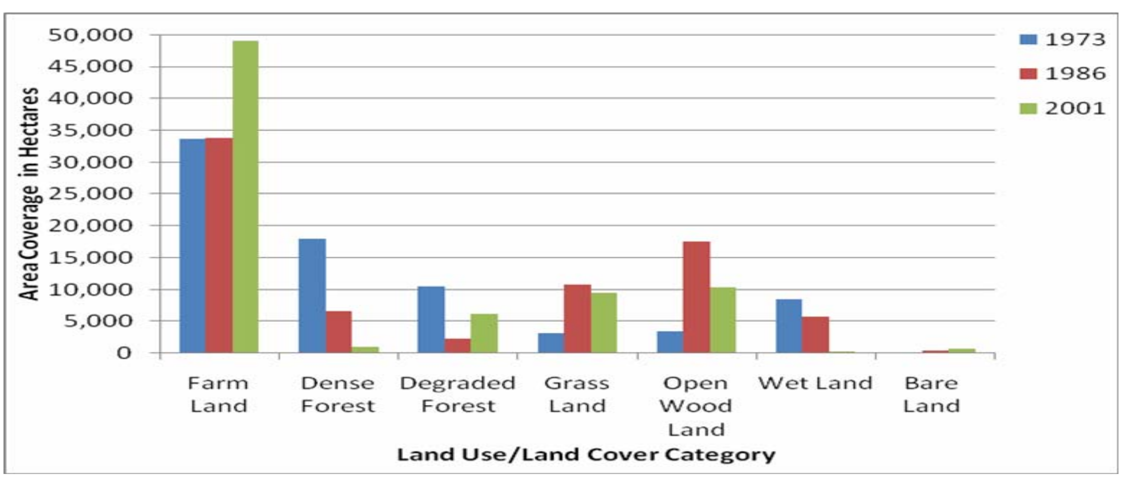

Figure 23: Graph of land use/cover across different years

Varying magnitudes of change has been recognized over the study period. Some categories increased and thus has positive mean rate of change but others were diminished and thus have negative rate of change. Looking in to the extreme values on figure 24 can give a clear picture of human use of land resource relation in the study area. Natural land resources are diminishing but derived land resources and cultural landscapes are expanding. The rate of change of farm land indicates an ever expanding in positive direction. Grassland and open wood land are the next showing increment from year to year. In opposite direction, dense forest has diminished much more at a faster rate from year to year. Wet land and degraded forest are the other next categories diminishing.

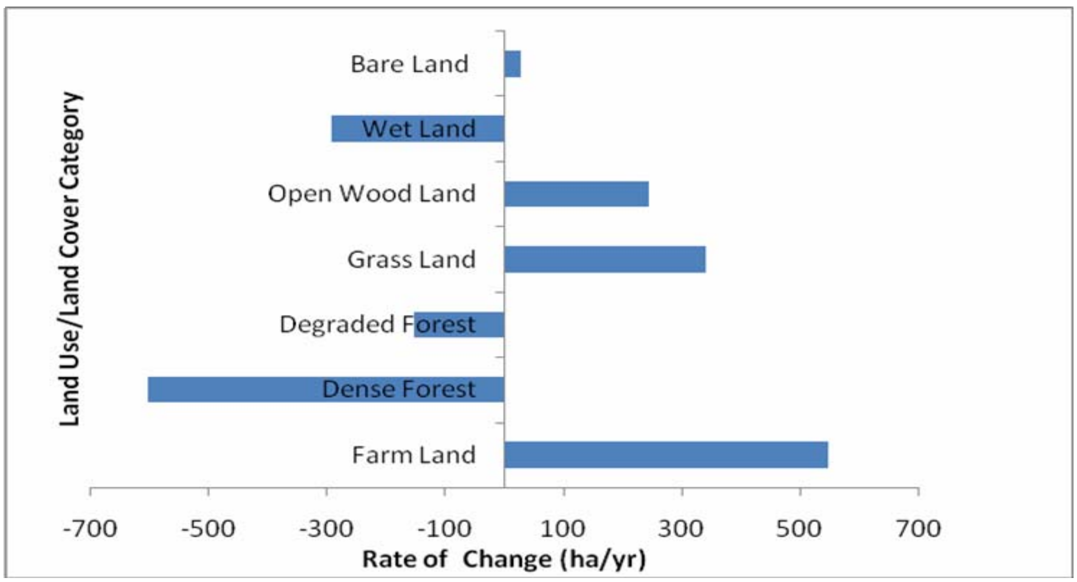

Figure 24: Rate of change of land use/cover across 1973 - 2001

Generally, in assesing the whole period of the image data statistics in the aformentioned tables and graphs, significant land transformation has been recorded. Those natural land cover types at the beginning were converted to cultural landscapes. The map on Fig. 14 can give a clearly view of the state of each land use land cove category at the respective time periods.

5.1.4 Land Use/Land Cover and Slope

The pattern of land use/cover correlates to a great extent with the slope of a given area. Agriculture is perhaps one of the activities that largely depend on slope especially in areas where rainfall is intense. Expansion of agriculture over steep slopes results in a disastrous effect towards soil resources. Towards this analysis over the study area, the slope derived from SRTM data has been reclassified into 4 levels and the areal extent of the slope and land use/cover class in each zone has been tabulated in ArcGIS environment.

Table 15: Land use/cover distribution across slope category

Land Use/Cover	Land Class Extent across Each Slope Category (ha)				
	$<5^0$	$5^0 - 12^0$	$12^0 - 25^0$	$>25^0$	Total
Intensively Cultivated Farm Land	12379	19507.34	10602.9	819.21	43308.45
Moderately Cultivated Farm Land	1552.35	2569.75	1556.75	25.3	5704.15
Dense Forest	154	204.8	620.2	94.4	1073.40
Degraded Forest	892.8	2474.8	2520.7	346.1	6234.4
Open Wood Land	4183.5	2826.5	2616.5	713.8	10340.3
Grass Land	7147.5	1276.4	933.3	201.4	9558.6
Wet Land	186.9	30.4	51.5	0	268.8
Bare Land	174.8	223.5	220.3	151.3	769.9
Total	26670	29113.49	19122.15	2351.51	77258
%	34.5	37.7	24.8	3.00	100

As can be seen from table 15, the slope category with $<5^0$ has been categorized as gentle slope and it covers 34.5% of the area. Most of this slope category falls in the low laying Didessa valley and hence mostly occupied by grass lands (7147.5 ha) and open wood lands (4183.5 ha). Moderately cultivated farm lands are the recently established land use systems that possesses the next extent (1552.35 ha) in this slope category. Intensively cultivated land has 12379 ha share over the category. It is the dense forest that has least share in this slope class.

The slope class from 5^0 - 12^0 has been categorized as moderate to sloppy possesses more area of Jima Arjo (37.7%) and it is in this class that intensive farming has its maximum share (19507.34 ha). Open wood land and moderately cultivated land are the next in areal extent. Others have intermediate to low share where wet land shares the least.

Sloppy to steep slopes (12^0 – 25^0) with 24.8% cover of the total area is still where intensive farming is dominant (10602.9 ha) over the other land use/cover classes. It is in this category that forest land is relatively has more concentration and wet land has the least areal extent (51.5ha). The other land use/cover category falls in between.

Strongly steep slope ($>25^0$) covering about 3% of the area possesses maximum extent of the intensive farm land (819.21 ha). Open wood land, degraded forest, grass land and dense forest lands with respect to their extent occupy intermediate to low shares. No wet land has been discovered over this slope category.

In general, the data shows, over the fragile steep slopes ($>12^0$) that should have been kept for either tree crop production or forest land, farming has become dominant (plate 8). The forest land (both the dense forest and degraded forest) which has been concentrated more in this slope category are likely to be under greater threat. It implies how much the area is prone to erosion hazard (since sever erosion is expected over steep slopes than gentler slopes) and the consequent soil and land degradation.

Plate 8: Farm land across the steep slope of Lalo Hine PA *(photo by Muleta, April 2009)*

5.2 Land Use/Cover Change Susceptibility Assessment and Mapping

In order to address the state of land use/land cover change and its impact, the identification of prone areas is of vital importance. In the study area, an attempt has been made to locate change and the then susceptible areas. In accordance with the description given under 4.1.2, 10 factor layers that affect land use/cover were generated. Pair wise comparison has been made among each of the factor layers in the IDRISI Andes GIS decision support tools and the weight of each layer has been obtained. Using the weight values, weighted overlay has been made to the factors (eq. 6) in the ArcGIS 9.2 software spatial analyst raster calculator.

*Susceptibility to Change = LU/LC * 0.1733+ Agro-Climate * 0.0559+Slope*0.1947+Soil type * 0.0551+Distance from All Weather Roads * 0.1460 + Distance from Dry Weather Roads * 0.1127 + Distance from Foot Paths * 0.0856+ Distance to Towns * 0.0854+ Proximity to Rivers * 0.0912…………………………….. (6)*

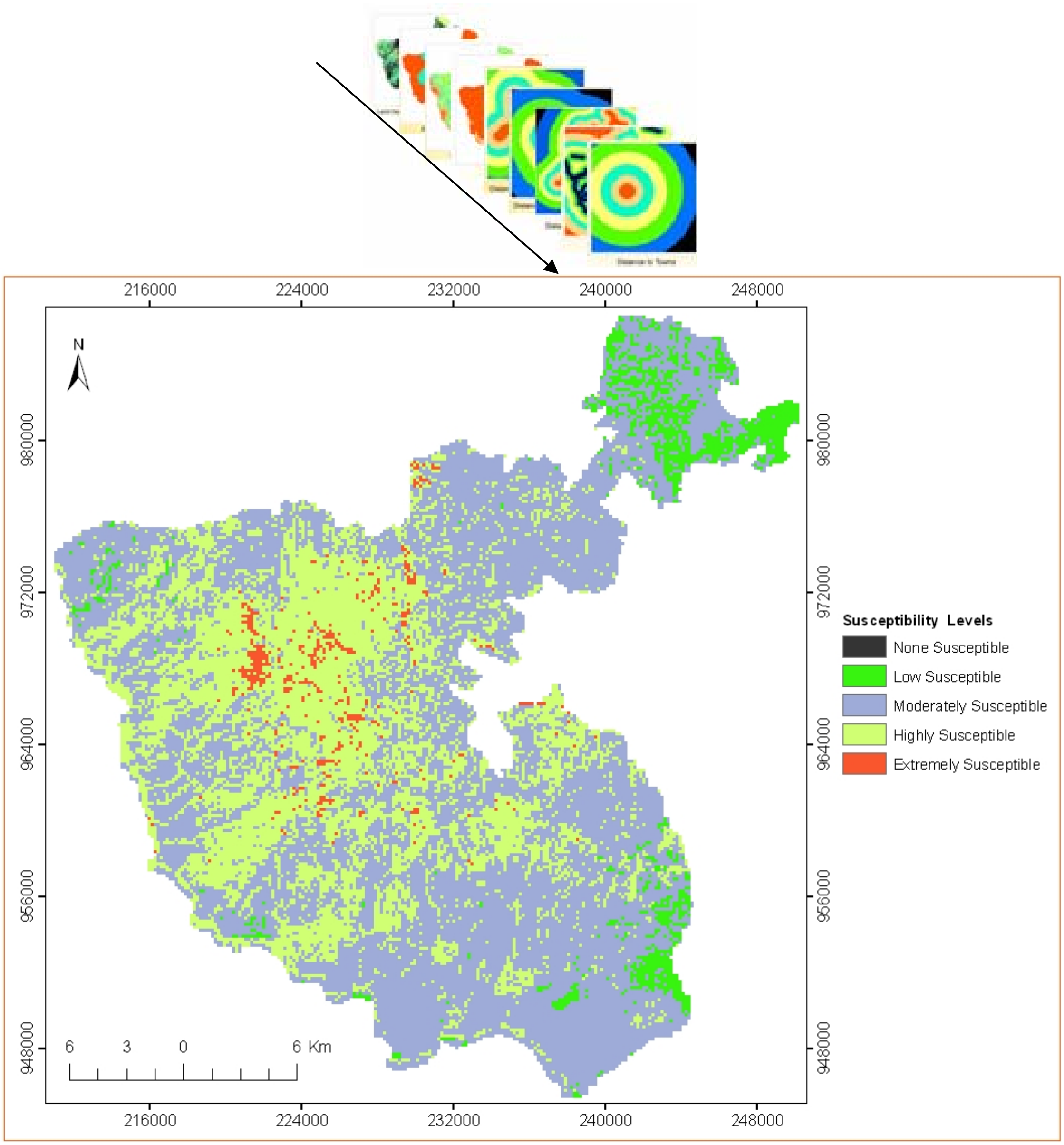

Figure 25: Map of land use/cover susceptibility to change

Figure 25 clearly gives visual impression and shows the level and areas susceptible to change. The statistical extent and distribution of each land use/cover across the change susceptible levels has been given in table 16. Accordingly, 9.7% has low susceptibility, 62% is moderately susceptible, about 25% is highly susceptible and 3% is extremely susceptible to change. Among the vegetation categories in the area, degraded forests were signified as the most susceptible to extreme change followed by dense forest. A substantial extent of grasslands, degraded forest land and wood land respectively again fall in the moderately susceptible category. Farm land, although dominant in all susceptibility levels with larger area in the moderately susceptible category, it is not a case in the extremely susceptible category.

Table 16: Levels and extent of land use/cover change susceptibility prediction

Land Use/Cover Class	Areal Extent of Susceptibility to Change (ha)					Total
	None	Low	Moderately	Highly	Extremely	
Farm Land	0.5	6636.1	35171.5	6811.2	393.3	49012.6
Degraded Forest	0	23.58	682.92	4326.21	1201.69	6234.4
Open Wood Land	0	151.65	3809.7	6236.39	142.56	10340.3
Grass Land	0	549.18	7815.42	1183.2	10.8	9558.6
Bare Land	0	27.99	301.59	151.92	288.4	769.9
Dense Forest	0	0.54	62.64	718.56	291.66	1073.4
Wet Land	0	69.48	178.56	20.76	0	268.8
Total	0.5	7458.52	48022.33	19448.24	2328.41	77258
%	0.0006	9.7	62.1564	25.143	3	100

5.3 Soil Loss Estimation using USLE Model

Soil erosion is a hazard traditionally associated with agriculture and is determined to have a long term effect on soil productivity and sustainable agriculture. It has also a wider significant effect on other land use categories and to the environment in general.

5.3.1 Application of USLE Model

The distribution and rate of soil loss over certain area is a function of the spatial distribution of all factors controlling soil erosion process. As described under 4.2, the USLE model has been used to assess soil loss and its distribution in the study area. The model estimate the amount of annual soil loss as a function of the parameters: rainfall erosivity (R), soil erodability (K), slope gradient (S), slope length (L), cover management (C) and soil erosion management practice (P) factors. It considers the weight of each parameter and hence each pixels of the raster layer for each parameter were multiplied.

For the study area actual soil loss estimation using USLE model, all of the factors were derived as raster layers. Using the formula derived by Wischmeier and smith's (1978) (eq. 5) and modified factors to the Ethiopian conditions by Hurni (1985) cited in krauer (1988), the cell to cell multiplication of the derived six parameter layers have been accomplished in ArcGIS 9.2 spatial analyst environment.

$$A = f(R \times K \times L \times S \times C \times P) \quad (5)$$

Where: A is the mean annual soil loss per hectare in tones;
R is the rainfall erosivity;
K is the soil erodability;
L is the slope length factor;
S is the slope steepness factor;
C is a cover management factor and
P is a supporting practice factor.

As can be seen from the statistics and map out put of the cell to cell multiplied parameter layers (Fig.26 and 27), the area has significant levels of soil loss that vary from about 0.03 t/ha/yr, the lowest, to 184.4 t/h/yr, which is the highest. The mean annual soil loss is 20.6t/ha/yr. This is the real indicator of the existence of the risk of soil erosion in the area.

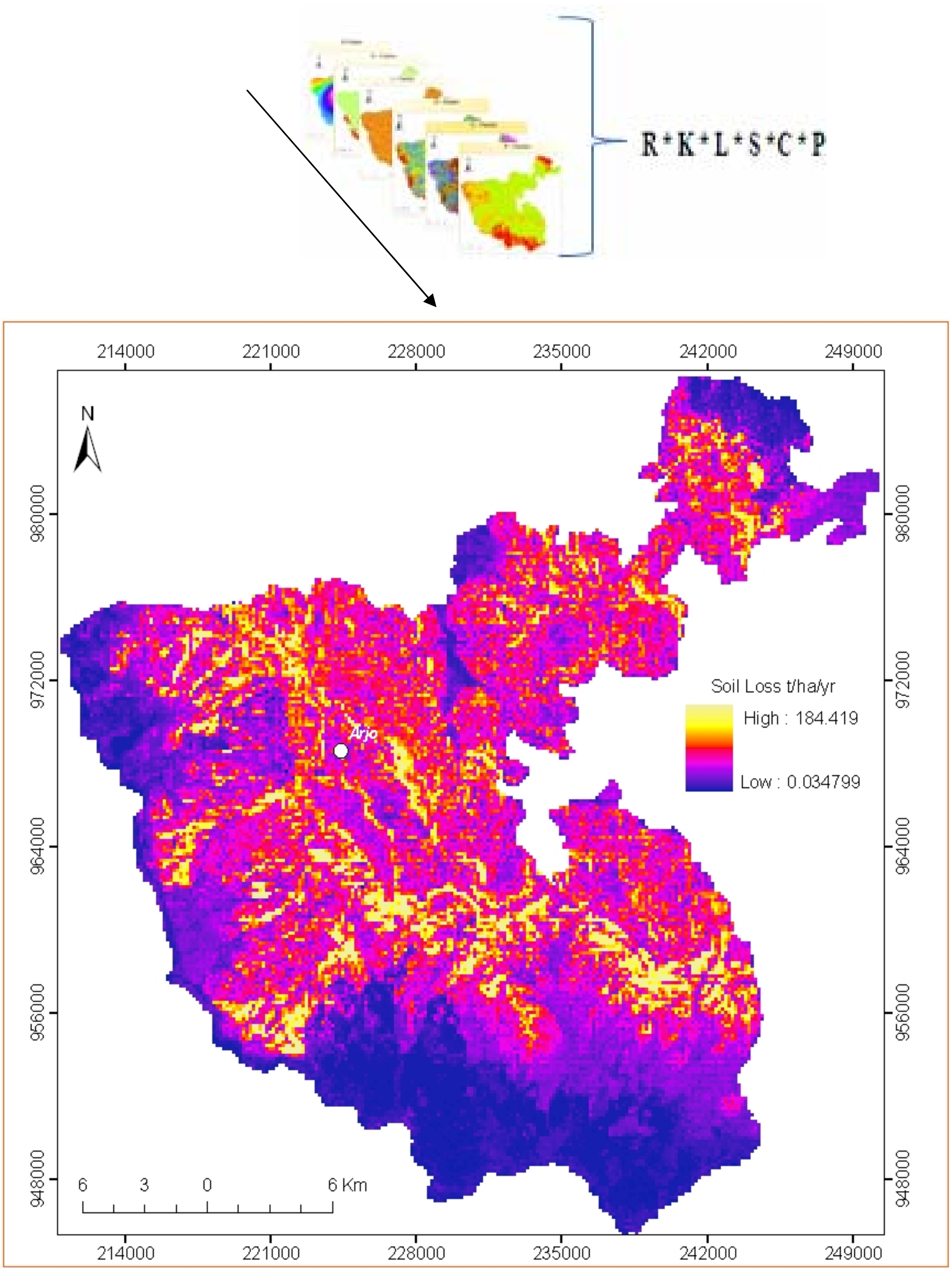

Figure 26: Soil loss estimation map of the study area

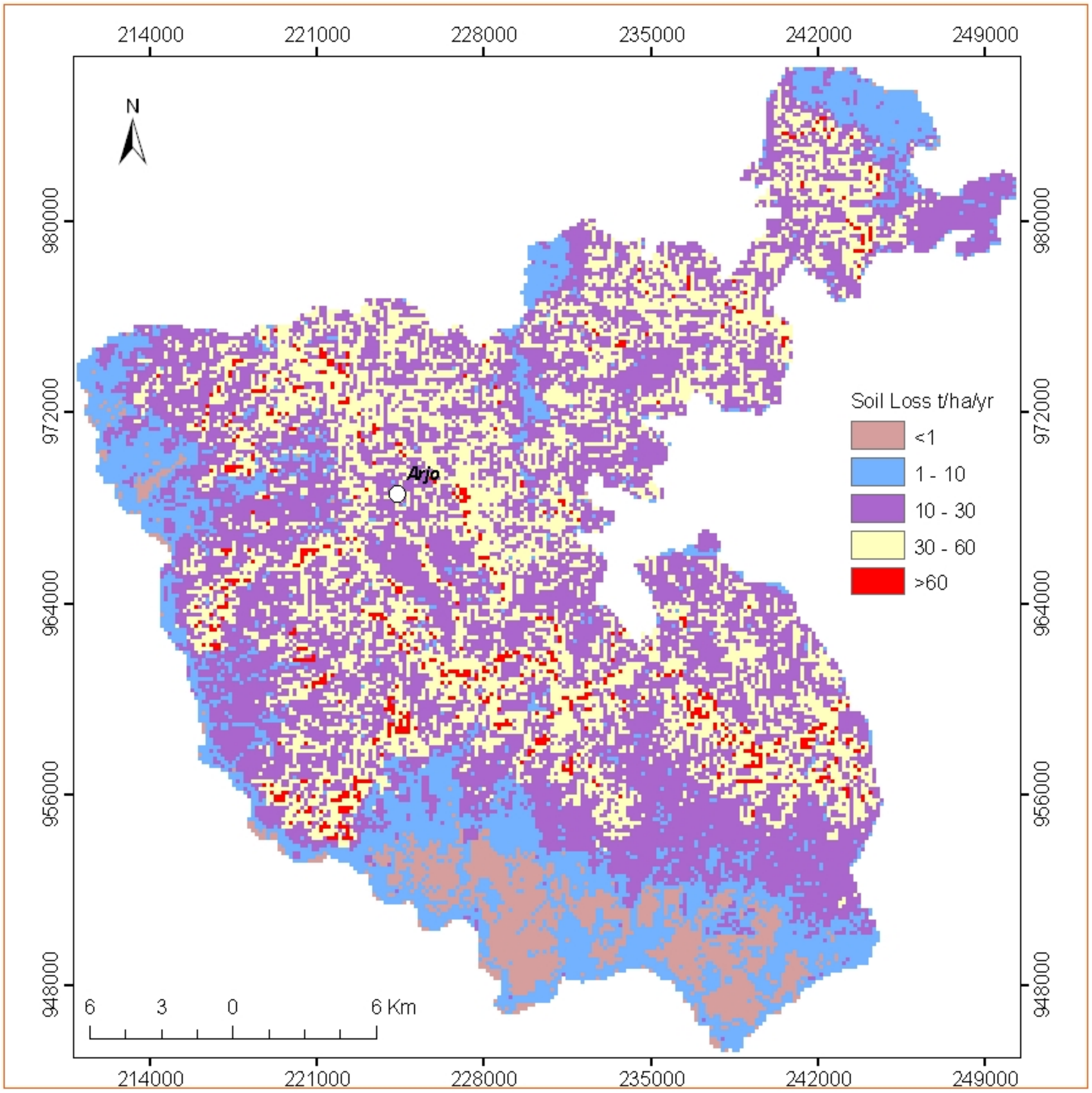

Figure 27: Map of actual soil loss levels of the study area

The quantitative out put of the predicted soil loss has been reclassified in to 5 tentative erosion hazard levels to assess its areal extent in a less difficult way (Table17). Accordingly, greater than 63% of the area looses more than 10t/ha/yr of soil. From this about 6% of the area is signified as high erosion hazard zone where more than 60t/ha/ of soil is removed per annum. This is observed more over the highland and mid altitude areas than the low land areas. The gullied hillsides of the Tibe ridge in Tibe Chafe and that of Wayu Abayi at the side of footpaths in Jarso Kiltu PAs can be noted as the long term effects of such erosion in the area (Plate 1 and 3). High to highly sever soil loss is evident on 27.9% of the area and almost a comparable coverage (26.6%) experiences low to very low soil loss. A relative wider area of the Woreda (35.5%) has moderate to high degree of actual soil loss (35.5%).

Table 17: Erosion level and areal extent

Class	Degree of Actual Soil Loss	Soil Loss Range (t/ha/yr)	Area	
			Hectares	%
1	Very Low	<1	7829.57	10
2	Low	1 – 10	20715.65	26.6
3	Moderate to High	10 – 30	27512.56	35.5
4	High	30 – 60	16917.55	22
5	Highly Sever	>60	4582.67	5.9
Total			77258	100

5.3.2 Soil Loss Distribution By Land Use/Land Cover

Soil erosion, although a natural phenomenon, its rate and level is highly correlated with land use activities and land cover types. Table 18 clearly shows the type of land use/cover and their contribution to soil loss for the area under investigation. The two extreme levels of soil erosion are recorded over the two opposite land cover types (the cultivated and the natural landscapes). Highly sever erosion is widely recorded over wider areas of cultivated lands: 3630.78 ha of the intensively cultivated land and 878.05 ha of the moderately cultivated land. On the contrary, very low soil loss has been experienced by the natural vegetations over the area: 6758.06 ha of open grass land followed by dense forest and wet land with 879.41 ha and 179.87 ha, respectively. The other land use/covers areal extent mostly falls in between. Parts of the bare land and the degraded forest experience sever soil erosion.

Table 18: Soil loss by land use/ land cover

Land Use/Cover Category	Areal Extent (ha)					
	<1t/ha/yr	1–10t/ha/yr	10-30t/ha/yr	10-60t/ha/yr	>60t/ha/yr	Total
Intensively Cultivated Land	0	7783.2	17892.36	14002.11	3630.78	43308.45
Degraded Forest	0	2284.21	3399.57	547.47	3.15	6234.4
Woody Land	0	6779.77	2907.43	652.11	0.99	10340.30
Open Grass Land	6758.06	2637.45	463.09	0	0	9558.6
Moderately Cultivated Land	12.23	772.32	2438.42	1603.13	878.05	5704.15
Dense Forest	879.41	193.99	0	0	0	1073.40
Swampy Land	179.87	87.94	0.99	0	0	268.8
Bare Land	0	176.77	410.7	112.73	69.7	769.9
Total	7829.57	20715.65	27512.56	16917.55	4582.67	77258

5.4 Interpretation of Interview Responses

In addition to assessing remotely sensed data, it is helpful to know how the community and the concerned personnel perceive the land resources to understand the status and future trend of land use/cover and soil. This is because their attitude and knowledge (especially that of the farmers and agricultural development experts) towards resources is influential in inducing change. To this perspective, structured interviews were made with the sample community members at different part of the study area. The Woreda's Agricultural and Rural Development office workers were also interviewed in order to cross check the response of the community members.

As per to the interview made with sample community members, they all were farmers and except 17.7% of them which do not have any livestock, all are practicing mixed agriculture (animal raring and crop production). 26.8% of them were land less and found leading their life either haired, renting a land or engaged on daily labor work. Only 6.5% of them were found to have enough farm land. Except 8.9% of them, all were native to the area. They all described as there is land cover change and one elder of 75 years old pointed out that Didessa valley and side slopes in the last few years were covered by bush, savanna grass and dense forests. They were once homes of lions, buffalos and hippopotamus (in Didessa River). Except on few foot paths walked by able persons, there was no any access to Didessa area. He also stated that the highlands were mostly wet and marshy and hence no body can cross such lands even recently. Now, such areas as observed, are all cultural lands (some are built up areas and others are farm lands). The respondent also emphasized that much of the land conversion and vegetation resource degradation has been observed at the end of the Dergue regime and the transition period that led to the current government.

91.1% of the sample community members stated that the extent of their original farm land has diminished. All of them (100%) stated as the yield they obtain from a given plot of land is declining from time to time. They were still opting for forest land if available while realizing the impact of the unwise consumption of the resources. As stated by 62.2% of the respondents, they were at a state of none self sufficiency and hence to fulfill the timely demand for them selves and their family requirements they were engaged in cutting and selling wood, wood products and grasses, illegally as a means of additional income generation. During the field work it has been observed that women were engaged in fuel wood and charcoal making and selling them to obtain additional income. Men were engaged in timber making and other forest resource extraction (Plate7).

The data obtained from the Woreda's agriculture and rural development office strengthens as there is land transformation driven by population increase and agribusinesses. Over the increasing population of the area, the recent resettlement program of the government to relieve population pressure in severely damaged regions brought much burden to the ecosystem of the area. In 2003, 865 and in 2004, 1566 settlers were settled over the unoccupied flat laying Didessa area. The then allocation of land to the land less on which they might attain self sufficiency continued. The agricultural experts in the Woreda added that the recent establishment of sugar factory that requires much land aggravated the problem. These all let the natural landscape to be converted in to cultural landscape. From the projections they made based on the previous studies conducted in the area, they pointed out as the farm land in the current year possesses >80% of the total area of the Woreda.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The major conclusions of this study are:

- A broader change and dynamics of land use/cover associated with broader range of impacts on the terrestrial resources of the area have been signified. Only 360.57Km^2, (0.5 %, of the area), left unmodified or unchanged at the final state of the study period (2001). Strongly steep fragile slopes (>25^0) have been converted to intensively cultivated farmlands (819.21 ha). The biotic diversity and the soils of the area were made susceptible to the impacts and the subsequent degradation. Large patches of the native (natural) vegetations have been converted, modified and some of the rest which are in their natural state were made prone to threats to a degree that surprises. Areas of trees have been most dramatically altered. The original natural dense forest land covering 23.2% of the total area at the initial study period (1973) has dropped down to 1.4% at the final study period owing to conversions to farmland and giving way to derived grass lands, open wood lands and degraded forest vegetations. The degraded forest land at the beginning (13.64%) has been converted and modified and left with 8.1%. Wetland is the other that diminished by 292.3ha of rate per annum. Recent years signified as periods when the change is more dramatic. About 28% of the area has been recognized as highly to extremely susceptible and 62.3% is moderately susceptible area to change.

- Soil degradation is the problem associated with land cover and/or land resource degradation signified in the study area. Soil loss which has been estimated using USLE model is an evidenced cause for the degradation. The area looses an average rate of 20.6t/ha/yr of soil.

- Some of the productive lands and soils were made unproductive and so abandoned. While the extent of farm land in general is increasing at a faster rate over the area, it is declining for an individual farmer. The crop yield produced by a given plot of farm land is declining from time to time. This in turn is challenging the community's needs fulfillment and self sufficiency.

- Agriculture played a decisive but not an exclusive role in the land use/cover dynamism and the then land degradation over the area. Besides farming, the unwise use of forest and natural land resource consumption has to be blamed for the natural land resource degradation over the area.

6.2 Recommendations

Based on the results of the study the following points are outlined as recommendations.

- Land use/land cover change in the area should be assessed and monitored timely using remote sensing and GIS.
- Forest and soil conservation study at feasibility level shall be carried out with full participation of the beneficiaries so as to restore the degraded areas.
- Local knowledge based soil conservation techniques shall be integrated in soil conservation strategy.
- Sustainability of soil and land resources shall be accomplished through increasing awareness on land resource management and the role of gender equality.
- Appropriate tillage methods suitable for each agroclimatic zone and slope should be identified and implemented.
- Rehabilitating gullies through controlling runoff in gullies shall be of greater importance.
- Alternate energy sources shall be available in the area to discourage fire wood and charcoal consumption and illegal tree cutting.
- There should be responsible and operational institutions, lows and policies to protect land resources and encourage their sustainable use.

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Annex I

Socio-economic Survey

I. Interview Questions for Farmers

A. General Background

1. Peasant Association ____

2. Sex __________ 3. Age _____________ 4. Marital Status _________________

5. Family size by age group: < 18 ____ 18 – 60 _______ >60 ________________

6. Educational Status of the family heads (Put - X)

S. No	Educational Status	Husband	Wife
6.1	Received formal education		
6.2	Received Basic education		
6.3	Hasn't received both		

7. Are you native to the area?

8. If you are not, why you come? A/ Land scarcity B/ Resettlement C/ Specify if other

B. Information about land use/cove

1. Which agricultural activity you engaged on? A/ only farming B/ only livestock raring C/ Both

2. If you engaged on farming do you have farm land? A/ Yes B/No

3. If you don't have farmland, how do you farm? A/Being haired, B/ Renting land C/what other options

4. What happen to the extent of natural vegetation in your local area? Increased or diminished

5. If diminished what major causes have you observed?

A/ Farming B/ overgrazing C/ Extraction of forest products D/ Fire E/ Mention for others

6. What is the trend of your farm land from year to year? A/ expanded B/ Diminished C/ Unchanged

7. If diminished, what reasons do you think?

A/ land degradation B/ Shared among family members C/ erosion D/ Mention if other

8. When it declines what measures do you do you take?

A/ Changing to other land covers B/ Use fallow methods C/ Use fertilizers D/ mention if other

9. If you want to change to other land cover which land cover you opt for?

A/ Forest land B/ Grassland C/ Woodland D/ Wetland E/ Bare land

10. What is the trend of the yield you obtain from a given plot of land from year to year?

A/ Increased b/ Decreased C/ Unchanged

11. Is the income you obtain from farming occupation cover enough your and your family expense?

A/ Yes B/ No

12. If not enough, from where you generate additional income?

A/ fuel wood and charcoal selling B/ Timber making C/ Daily labor work D/ mention if other

II. Interview Questions for the Woreda's Agriculture and Rural Development Office

A. General Background of the Respondent

1. Your Position ____ 2. Your Service years _______

B. Land Use/Land Cover and State of Soil Information in the Woreda

1. On what agricultural activity the community of the Woreda is engaged?
2. Is there enough farm land for the farming community?
3. If farmland is not enough for the farming community in the Woreda, what causes are prevailing?
4. What is the way of survival of those that do not have farmland?
5. What is the trend of land use/cover in the Woreda?
6. If changes were recognized, which land cover has been made susceptible and why?
7. What is the trend of total production per unit area from year to year?
8. What measures peasants take when the productivity of their farm declines?
9. What is the state of the soil in the Woreda?
10. What measures were made to alleviate soil erosion and degradation problems in your area?
11. What is the implication of human activity and land resource interaction in the Woreda? What would be its impacts on the soil?
12. What attempts have been made to sustain land resources and to solve soil degradation problems in the Woreda?

Annex II

Image Classification and Interpretation Ground Control Points

S.No	X	Y	LU/LC
1	225025	969007	built up Area
2	225195	969209	Grassland
3	225202	969165	Degraded forest land
4	225180	969225	built up Area
5	223140	969185	built up Area
6	222281	972310	Farmland
7	222316	972318	Farmland
8	222376	972392	Grazing land
9	222466	972370	Open woodland
10	222510	972385	Farmland
11	223908	970347	wet land
12	223924	970382	Farmland
13	224546	969610	Bare land
14	223564	967149	Grazing land
15	223508	967148	Grazing land
16	223517	967206	Built up area
17	223423	967250	wetland
18	223429	967227	Bare land
19	223294	967260	Degraded forest land
20	223202	967266	Degraded forest land
21	223122	967266	Degraded forest land
22	223135	967366	Degraded forest land
23	222942	967629	Farmland
24	222909	967696	Farmland
25	223262	967736	Degraded forest land
26	221412	964584	Farmland
27	219669	964549	Farmland
28	218924	963676	settlement
29	218939	963677	Farmland
30	222295	964713	Farmland
31	222283	964725	Open woodland
32	227800	960998	Bare land
33	224750	967895	Bare land
34	220976	966333	Farm land
35	233141	960817	Farm land
36	226987	963904	Farm land
37	227039	963902	Farm land
38	227102	963973	Wetland
39	233919	961679	Farm land
40	233798	961634	Farm land
41	226714	964439	Open woodland
42	226669	964559	Open woodland
43	226563	964983	Wetland
44	226599	965073	Wetland
45	226495	965114	Open Woodland
46	226389	965169	Irrigated farm land
47	226131	965297	Irrigated farm land
48	226045	965585	Wet land
49	226105	965916	Open woodland
50	226181	965959	Irrigated farm land
51	226152	966032	Farmland
52	224840	968798	Built up
53	225933	968928	Farm land
54	229268	974685	Degraded forest land
55	230037	971151	Farm land
56	219891	974571	Grass land
57	221744	969384	Open woodland
58	233742	951828	Bare land

Declaration

I, the under signed, declare that this thesis is my work and that all sources of material used for the thesis have been dully acknowledged.

Name: Muleta Ebissa Feyissa

Signature: __________

Place and date of submission

June 2009, Addis Ababa